DEPARTMENT OF
ENERGY, MINES AND RESOURCES
OTTAWA, CANADA

annual report 1970-71

Hon. Donald S. Macdonald, Minister

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Mica dam, Columbia River development project, British Columbia.

New Directions

As a result of important and far-reaching policy decisions, the Department of Energy, Mines and Resources has been charged by the Government of Canada with increased responsibilities in the safeguarding and development of the nation's energy and minerals resources. In order to sharpen and to emphasize this new thrust in the Department's activities, and to free it for its vital new tasks, it was relieved of responsibilities for water research and astronomy, which were transferred to other agencies.

Critical issues facing Canada's energy and mineral economy include the implications of tax reform, the need to expand foreign markets while encouraging further processing at home, environmental problems caused by

mineral and energy development, Canadian control and ownership of energy industries, U.S. import quotas on Canadian oil, and the maintenance of a viable uranium industry.

The new Department of Energy, Mines and Resources that took shape during the report period of 1970-71 viewed its tasks and responsibilities not only in the light of technical and economic factors, but also social factors. What can our geological resources, known and unknown, contribute to Canadians, and at what cost? How much industrial growth does the nation want, how much foreign ownership is consistent with the welfare of the Canadian people, and what will the impact be on the environment and the standard of living? Will a certain policy reduce or increase regional economic disparity? These are some of the questions faced by EMR policy advisers, in common with all other departments.

The Department conducts its activities under three main heads — energy, which covers policy on electric power, petroleum, coal, uranium; mineral development, which covers policy recommendations on all mineral commodities; and science and technology, which covers surveys and research in such fields as mapping, geology, metallurgy, mining technology, geophysics, and provides the basic data on which policies are necessarily based.

ENERGY DEVELOPMENT

The Energy Development Sector of EMR seeks to influence the development and use of Canada's energy resources in such a way that they will produce the maximum benefits for Canadians of the present as well as future generations. To this end, its experts collect and analyse data on all activities and supply-demand conditions in the field of petroleum, natural gas, coal, uranium, and electrical power, and they make policy recommendations to the federal government based on these analyses and on projections into the future. They also control and manage oil and gas exploration in offshore regions, including operational, conservation, safety and anti-pollution measures.

In the field of electric power, a highlight of the year was the signing of an agreement between Canada, Quebec, and Hydro Quebec providing for federal financial assistance to the Hydro Quebec Research Institute. Under the agreement, Canada will lend Hydro Quebec $17.5 million, repayable over 25 years, and make ten annual grants of $325,000 each. The agreement stipulates that the institute will serve the entire Canadian electrical industry, especially with research in high-voltage and high-power transmission. A review board and a technical advisory committee, both with national representation, were set up to ensure that the overall objectives of the institute are achieved.

Emphasis in oil and gas exploration is now placed on the frontier areas of the far north and the offshore areas on the east coast. In December 1968, the government established the Task Force on Northern Oil Development for interdepartmental advice and co-ordination. Under the chairmanship of the Deputy Minister of EMR the task force has been conducting appraisals of pipeline engineering, environmental control, marine transportation, oil and gas marketing, and the economic impact of northern oil development and pipeline activity. Recommendations concerning policy for northern pipelines were published in August 1970 to provide industry with a set of guidelines for planning the construction and operation of pipelines from Arctic regions to southern markets.

The National Oil Policy, under which that part of Canada lying west of the Ottawa Valley is reserved for domestic oil, continued to be reviewed in the face of economic pressure from foreign-produced oil.

During the period 1963-70, the federal government spent $101 million on a program for stockpiling uranium oxide, of which it accumulated 19 million pounds. A further $39 million is to be spent in the years 1971-74, for 6.3 million pounds from a joint program with Denison Mines Limited, the largest Canadian supplier of uranium. A new Crown corporation, Uranium Canada Limited, was incorporated in 1971 to act on the government's behalf in the acquisition and later disposal of the stockpiles. These actions will help to ensure the existence of a viable Canadian uranium industry during the rapid world-wide expansion of nuclear-reactor use predicted for this decade.

The question of foreign ownership of uranium mines in Canada is an important part of the question of foreign ownership of Canadian resources. In March 1970 the federal government announced a policy, according to which any sales of foreign holdings in any uranium-producing company must be made to Canadian residents, until the total foreign ownership is reduced to 33 per cent. Also, no foreign investor, or group of associated foreign investors, will be allowed to retain more than a ten-per-cent ownership in a uranium property.

The Energy Development Sector contains the Resource Management and Conservation Branch, which provides recommendations and advice on offshore mineral resource

policies and programs, manages and administers federal interests in mineral resources off the east and west coasts and in the Hudson Bay and Hudson Straits regions, including supervision and control over exploration and development activities, and administers federally-owned mineral rights within the provinces. During the fiscal year 1970-71, a new bill amending the Oil and Gas Production Act was passed to extend the authority of the Act to operation, production and conservation matters of the offshore. The Act sets out conditions designed to protect the marine environment and to ensure the orderly and efficient development of petroleum resources.

During 1970, oil companies spent $37 million in the evaluation of offshore Canada Oil and Gas Permits administered by the Branch, an increase of $15 million over 1969. In that same year, the Branch approved 80 separate offshore exploration projects. At March 31, 1971, the Branch had issued 5,909 Canada Oil and Gas Permits, covering 414 million acres of the offshore.

MINERAL DEVELOPMENT

The Sector is concerned with mineral affairs from a resource management viewpoint. In structure, the Sector is composed of the Mineral Resources Branch and the Explosives Division.

The Mineral Resources Branch is concerned with resource economics. On resource problems connected with mineral development, it provides advice and analyses on both the short and long-range outlook for minerals in the Canadian economy including markets and supply-demand relationships.

This Branch is also concerned with encouraging and extending the pattern of development in Canada. In areas where minerals are a suitable vehicle for development, the Branch participates with other federal and provincial departments in studies and plans intended to further the development of mines, smelters or processing facilities and related transportation needs. Examples include: the Northwest Canada Resource Transportation Study, a mineral development program in New Brunswick, and an evaluation of the economic mineral potential of Manitoba.

Among the functions of the Mineral Resources Branch is administration of the Emergency Gold Mining Assistance Act (EGMAA), first passed in 1948 to extend the operating life of gold mines in economic difficulties and thereby to save the communities that had grown up around the mines. Amendments to the Act, which received Royal Assent in February 1971, extended the Act to June 30, 1973, and placed certain obligations on the gold mines to ease the effect of possible closure on employees.

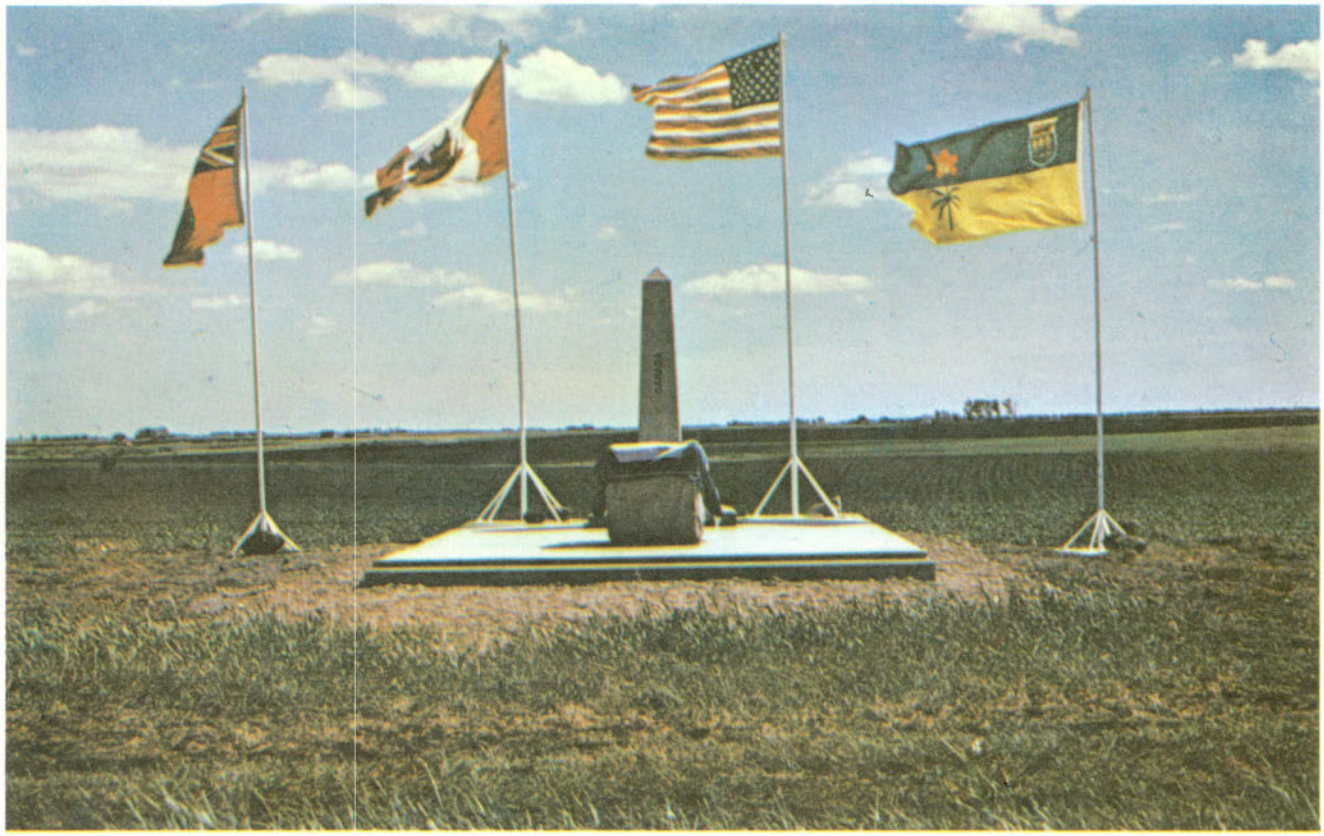
The Explosives Division administers the federal Explosives Act which covers factories that produce explosives and also transportation, storage and importation. Its work is designed to safeguard the public and promote safety.

SCIENCE AND TECHNOLOGY

This Sector is the Department's largest in terms of staff and facilities. During the period covered by this report, it embraced the Surveys and Mapping Branch, the Geological Survey of Canada, the Mines Branch, the Earth Physics Branch, and the Polar Continental Shelf Project. In 1971, two more autonomous units were formed within the Sector — the Canada Centre for Remote Sensing and the Atlantic Geoscience Centre.

Two projects of the Surveys and Mapping Branch, because of their vast scope and impact, caught the attention of the general public. These were the air photographs of the Prairies which were taken during the first two weeks in August in support of the Lower Inventories for Tomorrow program, and the start of the detailed mapping of the Mackenzie River valley, the so-called pipeline corridor. The air photography mentioned above was carried out to monitor adherence by farmers to the stipulations of the LIFT operation. Under the terms of this federal measure, which was announced in February 1970, farmers who reduced wheat acreage and increased summer fallow by a corresponding amount received federal compensation payments of six dollars per acre. The mapping of the Mackenzie Valley was required in order to assess the potential impact of pipeline and other industrial installations in that important area and to provide information for those interested in undertaking such development. Altogether, 120 maps were compiled at a scale of 1:50,000.

One of the top priorities of the Geological Survey of Canada is the completion of the national geological reconnaissance of Canada at scales of one inch to four miles and one inch to eight miles. It is estimated that at the present rate this task will be completed about 1976. Completion



Ornamental monument marking the intersection of the Manitoba, Saskatchewan and international boundaries.

of the reconnaissance phase will permit expansion of regional multidisciplinary analyses by integrated teams that is needed for objective evaluation of our national endowment of energy and minerals.

A new section was formed as a focus for the Geological Survey's expanding geological appraisals of oil and gas potential of the Atlantic coastal shelf and eastern Canada. The section is located in the Atlantic Geoscience Centre. Also important for petroleum exploration in that region was the Earth Science Symposium on Offshore Eastern Canada which took place in Ottawa during February 1971. The symposium was attended by 373 persons, of whom 215 represented private companies.

A new Division of Geological Information Processing was formed in April 1970, whose prime role is the transfer of scientific results to potential users with minimum delay. In addition to processing maps and reports for publication, introduction of a new system of prompt information release by open file was very well received.

In order to provide essential information on surficial materials and terrain sensitivity to construction, along possible routes of the Mackenzie Valley pipeline and transportation corridor, field mapping was started and preparations were made for a greatly expanded program by the Geological Survey.

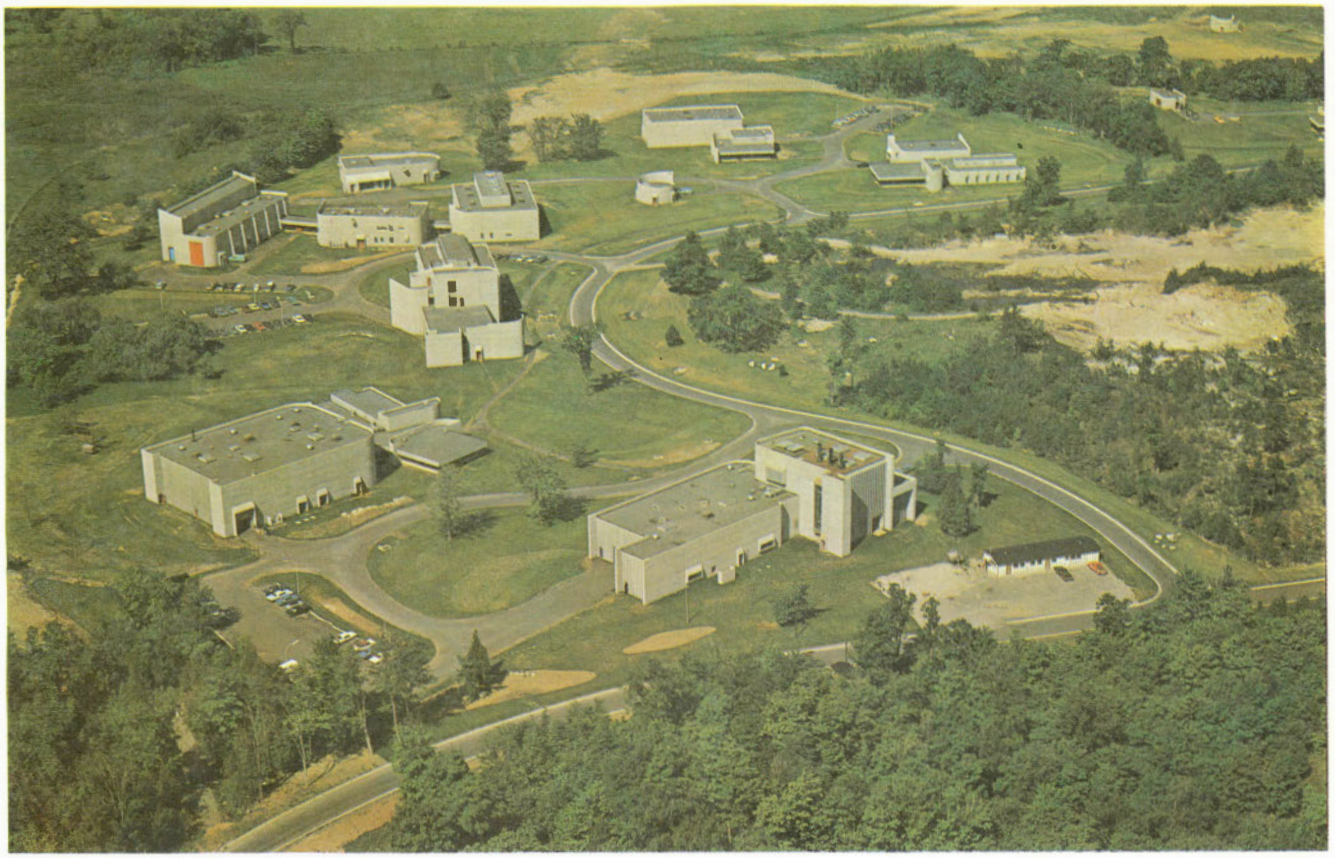
A hydraulic flume of advanced design with an 18-metre channel was installed by the Terrain Sciences Division for purposes of studying factors controlling sedimentation, erosion, stream flow and flooding. Results will be useful in engineering design, mineral resource location, maintenance of channels, and erosion control.

For the Mines Branch, 1970-71 marked the completion of the relocation of its fuel-research facilities to new, improved quarters on the western outskirts of Ottawa. The fuels-research specialists achieved significant advances in their fight to reduce air pollution from combustion, both in removing pollutants from fuels and in reducing the harm from combustion gases by dispersal into the atmosphere.

The efforts to develop a satisfactory thermal method for destroying liquid DDT culminated in the construction of a $150,000 incinerator by the Defence Research Board at Suffield, Alberta, based on a design developed in the Branch's Canadian Combustion Research Laboratory.

The Branch also succeeded in devising a method of "finger-printing" oil from oil-spills at sea, thus making it possible to track down the offending carrier.

Precise knowledge of ore composition in slurries is of great value in controlling ore dressing. The Mines Branch has



Mines Branch Research Centres complex at Bells Corners, outside Ottawa.

made significant contributions in the development of ore-slurry analysis by the use of radioisotopes, which are compact and portable, directly on stream to give an instant read-out of slurry composition. It is expected that this approach to slurry analysis will find many uses in the mining industry.

The discovery and exploitation of large deposits of strontium sulphate in Cape Breton Island prompted Mines Branch experts to look into better means of extracting and using this rare element. A new concentration process was developed, using flotation. As to industrial application, work is proceeding on the use of strontium in ferrites, devices widely used in the manufacture of television sets and computers. Strontium research at the Mines Branch, both in the fields of extraction and industrial application, is a good example of the aid a government laboratory can give to an emerging industry and the economy of a region that is especially in need of such diversification.

One of the notable achievements of the scientists of the Earth Physics Branch occurred in the field of crater research. There are many identifiable ancient craters in the Canadian Shield, and controversy continues to rage whether these are of volcanic or meteorite origin. The discovery of the silica mineral coesite — the first such find in Canada — in the Lake Wanapitei crater near Sudbury has convinced the scientists that the crater was caused by the impact of a meteorite.

The Branch's geomagnetists studied the magnetization of rocks from Vancouver Island and came to the preliminary conclusion that 200 million years ago the island was not part of the North American continent but was located thousands of miles away in the central Pacific.

In the field of seismology, an important event was the publication by the Branch of a detailed evaluation of present world-wide seismic capabilities, entitled *Seismological Detection and Identification of Underground Nuclear Explosions.* The volume was distributed by the Canadian government at the 26th General Assembly of the United Nations.

The small staff of the Polar Continental Shelf Project continued to provide logistic support to various departmental and non-departmental scientific activities in the high Arctic. Noteworthy among these was preparation for the Arctic Ice Dynamics Joint Experiment (AIDJEX), which seeks to elucidate the interaction between fields of motion in the atmosphere, the pack ice, and the liquid ocean. Such an understanding is basic to forecasting ice conditions and other weather factors. The main program is scheduled to take place in 1973-74.

The Atlantic Geoscience Centre was formed around certain units and functions formerly part of the Atlantic Oceanographic Laboratory at Dartmouth, N.S., which

was transferred to the Department of the Environment. The research of the new centre is concerned chiefly with marine geology and geophysics. The most notable project of the 1970-71 fiscal year was the geophysical component of the HUDSON 70 project — the circumnavigation of the Americas by the Canadian Scientific Ship *Hudson* from November 1969 to October 1970. Scientists carried out extensive bottom sampling while the ship traversed the Beaufort Sea and did a seismic-refraction survey of Baffin Bay.

Closer to home, off the coast of Nova Scotia, the grounding and sinking of the Liberian tanker *Arrow* in February 1970 had released 2.5 million gallons of bunker oil into the sea, polluting Chedabucto Bay and its shore. The Atlantic Geoscience Centre used the opportunity to study the various self-cleaning processes of the ocean environment.

Canadian scientists and particularly the geophysicists of EMR have for some time been following the advances in remote sensing with keen interest. Remote sensing, as understood by the scientific community, is the scanning of the earth's surface from a distance with various types of instruments. Thus far, pre-eminence among sensors has belonged to the photographic and television cameras, notably in the infrared band of the light spectrum. Cameras and other instruments may be carried by high-flying aircraft, satellites, balloons or rockets.

In July 1969, the Cabinet Committee on Science Policy and Technology instructed EMR to establish an Interdepartmental Committee on Resource Satellites and Remote Airborne Sensing supported by a Program Planning Office (PPO), which undertook various preliminary studies on the role to be played by Canadian science, and particularly government science, in this new and exciting field of observing our environment and cataloguing its resources.

In August 1970, the government awarded $201,360 in contracts to eleven Canadian companies and universities for the development of remote-sensing devices.

In February 1971, Treasury Board approved the establishment of an organization in EMR to be known as the Canada Centre for Remote Sensing, and in May of that year, EMR signed an agreement with the U.S. National Aeronautics and Space Administration (NASA) according to which the Canada Centre for Remote Sensing would be able to receive imagery from a remote-sensing satellite (termed Earth Resources Technology Satellite) scheduled to be launched by NASA in 1972.

Energy Development Sector

ELECTRICAL ENERGY

The Energy Development Sector is primarily concerned with federal programs and policies for the production and transmission of electrical energy throughout Canada, and seeks to co-ordinate and encourage the best use of available energy resources. The Sector therefore has a special interest in power-system planning, including the various forms and the siting of generating and transmission facilities. Consideration is given to the economic and environmental factors associated with the development and production of electric power.

The interests of the Sector include support systems such as power-system control; communication; supply, transport and storage of fuel; research programs and facilities pertaining to power generation and transmission; and the development and improvement of electrical equipment and prime movers.

Power Development in the Atlantic Provinces

The Energy Development Sector continued its technical advisory role in connection with studies by the Department of Regional Economic Expansion concerning assistance to power projects that would be of major significance to the power systems of the Atlantic provinces. Discussions were continued with officials of the Department of Regional Economic Expansion and the maritime utilities, and the Sector sponsored a special study on the organization and operation of power pools.

The Sector continued the federal interest in tidal power arising out of the studies by the Atlantic Tidal Power Programming Board completed in the preceding year. Discussions were held with representatives of New Brunswick and Nova Scotia concerning developments that bear on the economic feasibility of Bay of Fundy tidal power, and at year end, discussions were taking place concerning a formal review of the ATPP Board report in the light of current circumstances.

Upper Yukon Power Market Study

A report *Upper Yukon Power Market Potential* was completed and issued by the Sector. This report summarizes the conclusions of the study undertaken in co-operation with the province of British Columbia, the British Columbia Hydro and Power Authority, the Department of Indian Affairs and Northern Development, and the Alaska Power Administration, on the market potential for power that could be developed by diverting a portion of the Upper Yukon River waters to a generating station located on tidewater in northern British Columbia or southeast Alaska. This study found that while the market potential for such power is not unfavorable it is evident that the combined potential markets of northern B.C., Yukon and Alaska would not be adequate to support the project; hence more remote markets such as central and southern B.C., and possibly the Pacific Northwest area of the United States, would have to be supplied to create a

viable project. The report identifies a number of additional studies required to confirm the various cost factors. It also recognizes that further consideration of this project would have to be accompanied by an intensive study of how the ecology and environment of significant areas of the Yukon and northern B.C. would be affected by partial diversion of the headwaters of the Yukon and the creation of storage on the Yukon and the tributary lakes and river systems.

Hydro Québec Research Institute

The Energy Development Sector was responsible for co-ordinating the work of several federal departments pertaining to federal assistance to electrical research, with particular reference to the electrical research institute being developed by Hydro Québec.

An agreement between Canada, Québec and Hydro Québec providing for federal financial assistance to the Hydro Québec Research Institute was formally executed by the Minister of Energy, Mines and Resources, the Minister of Natural Resources of Québec and the President of Hydro Québec, at a ceremony in Montreal in July 1970.

Under the provisions of this agreement, Canada will lend a total of $17,500,000 to Hydro Québec to assist in financing the capital cost of the institute, and will make a grant of $325,000 per annum to the institute for ten years commencing when the institute's high-voltage laboratory becomes operational, scheduled for 1971. The loan will bear interest at the rate applicable to funds advanced to federal Crown corporations and is repayable in 25 equal annual installments of principal and interest commencing not later than March 31, 1975.

The agreement recognizes and establishes that the objective of the institute is to meet as effectively as possible the needs of the Canadian electrical industry, including electric utilities and electrical and related manufacturers, and educational and government bodies. To achieve this the institute will provide appropriate research and testing equipment and skilled personnel capable of conducting investigations into equipment performance, materials and techniques related to economic and reliable methods of generating, transmitting, distributing and utilizing electrical energy, and will ensure effective dissemination of research results. In addition, it is provided that the institute shall endeavor at all times to give preference to Canadian clients.

The facilities being provided by the Hydro Québec Research Institute include high-voltage and high-power testing laboratories of a magnitude and capability unsurpassed on a world-wide basis, and currently not available elsewhere in North America.

In accordance with the agreement, a review board and a technical advisory committee have been established. The primary responsibility of the review board is to ensure that the objectives of the institute are achieved. The technical advisory committee, comprising representatives of Canada, Québec, Hydro Québec, and the electrical-power utilities and electrical-manufacturing industry of Canada, reports to the review board, and is empowered to advise the institute as to programs of work and procedures and courses considered desirable to achieve the aims and objectives of the institute. Officers of the Energy Development Sector are members of both the review board and the technical advisory committee.

During the year, loan installments totalling $10,900,000 were paid to Hydro Québec in accordance with the terms of the agreement. The review board and technical advisory committee were appointed and the review board held its inaugural meeting.

Columbia River Development

The Assistant Deputy Minister (Energy Development) continued his chairmanship of the International Columbia River Treaty Permanent Engineering Board, and the federal chairmanship of the British Columbia - Canada Columbia River Advisory Committee. The Permanent Engineering Board is responsible for ensuring that the objectives of the Columbia River Treaty are achieved. Under the treaty three Canadian storage projects were to be constructed. Two of them, namely the Duncan and the Keenleyside (Arrow) dams, have been completed and placed in operation. Construction of the Mica Dam, the largest of the three Canadian projects, is proceeding on schedule for completion in 1973.

The B.C. - Canada Columbia River Advisory Committee assists the federal-provincial committee of ministers involved in the implementation of the treaty by Canada. The Minister of Energy, Mines and Resources is the federal chairman of the ministerial committee.

Nelson River Power Development

The Assistant Deputy Minister (Energy Development) serves as chairman of the Federal-Provincial Nelson River Review Committee established in accordance with the Canada-Manitoba agreement signed in 1967. The agree-

ment pertains to development of the hydro-electric potential of the Nelson River.

Officers of the Energy Development Sector participated with other federal government officials in discussions concerning the supply of AC/DC converter equipment under the provisions of the agreement with a view to achieving maximum benefit to the Canadian electrical industry in the design and manufacture of solid-state converter equipment and the technology associated with the development of this relatively new type of power-transmission equipment, without detracting from the prime objective of the agreement relating to the transmission of Nelson River power to southern Manitoba.

Saskatchewan-Nelson Basin Board

To assist the Saskatchewan-Nelson Basin Board in its studies of alternative water supply and diversion routes, the Sector carried out a study of power costs that would be appropriate for meeting pumping-energy requirements for various alternative schemes. This study was based on the assumption of generation constructed for water pumping only and the alternative of supply purchased from provincial utilities.

High-Voltage Direct-Current Transmission

The Energy Development Sector, in conjunction with other departments and agencies of the federal government, has been assessing progress in this important new area of electrical transmission technology. Apart from activities associated with the Nelson River transmission system mentioned above, this work has included recommendations for financial support and encouragement to Canadian companies active in the development of equipment designs and system-engineering skills.

Thermal Discharge from Electric Generation Facilities

The cooling-water requirements of fuel-fired electric generating plants create concern because of the possibly harmful effects from the discharge of heated water to natural water bodies, especially where water supplies are limited. Arising from this there is an incentive to find beneficial uses for the low-grade heat energy involved. Both aspects have been forecast to the year 2000 by consultants' studies sponsored by the Energy Development Sector of this department and the Department of the Environment. A prime purpose of these studies has been to identify appropriate research well in advance of the actual occurrence of serious problems, and thereby ensure that adequate design and performance standards for thermal-electric generation facilities can be established.

Microwave Communication Facilities

Because of the benefits of large scale in microwave facilities the Department of Communications has been discouraging the proliferation of private microwave systems with the idea that most microwave-communication needs can advantageously be met by common carriers. On the other hand, electric utilities have special needs for extreme reliability and close operational control of communication systems used for operation of interconnected power systems. The Sector assisted the utilities and the Canadian Electrical Association in extensive discussions, the objective of which was to ensure that the special needs of electric utilities are adequately recognized in communication-policy development and in microwave licensing.

Electric Power in Canada

The publication *Electric Power in Canada 1969* was prepared and issued, and material for the 1970 issue and the regional map supplements was assembled. This annual publication of the Department summarizes developments in the generation and transmission of power in Canada. It includes a tabulation of all the major (over 1,500 KW) power developments in Canada, and the location and general particulars of all major transmission lines are illustrated in five regional map supplements.

OIL AND GAS

The Energy Development Sector makes appraisals and policy recommendations concerning the oil and gas industry in terms of developments in the resource, production, processing, transportation, and marketing components. Some issues may be viewed primarily with reference to the domestic economy while others are essentially Canada-U.S. or international matters although all, in the final analysis, are generally quite closely related. Appraisals

and policy recommendations relate to an industry in Canada which, while in existence for well over a hundred years, only became of national importance the past 25 years. It has experienced rapid growth in the past decade when crude oil production increases averaged almost 10 per cent a year, exports increased four times, and petroleum demand within the country advanced at an annual average of five per cent. The growth of natural gas has been even more marked. The government role in relation to oil and gas is widely accepted as necessary for an industry which is now of such national importance but which continues to operate as a free enterprise.

Frontier Resource Development

Emphasis in exploration for oil and gas is now directed to the "frontier" areas of the far north and the east coast offshore. In December 1968 the government established the Task Force on Northern Oil Development as an interdepartmental co-ordinating and advisory group. Under the chairmanship of the Deputy Minister of Energy, Mines and Resources, the task force conducts appraisals relating to pipeline engineering, environmental control, marine transportation, oil and gas marketing, and the economic impact of northern oil development and pipeline activity. Based on its appraisals, it makes policy recommendations to government. Recommendations made in mid-1970 concerning policy guidelines for northern pipelines were published in August of that year to provide industry with a set of standards for planning the construction and operation of pipelines from Arctic regions to southern markets. The task force has become increasingly active as preparatory work by three competing groups has proceeded towards the stage of application to build a northern gas pipeline, while another group of companies has been doing research in preparation for an oil pipeline. Concurrently, the task force has been carrying out its own environmental, engineering and economic research which will help to prepare the government for the assessment of pipeline applications when received. This research is also being used to develop further guideline criteria for industry in its planning of northern pipelines which will constitute some of the biggest construction projects ever undertaken in Canada.

The Canadian Market for Oil and Gas

About half the crude oil produced in western Canada finds a market within the country, and the rest is exported to the United States. Exports balance imports into eastern Canada from foreign sources. As a matter of national policy, domestic crude oil is used as far east as the Ottawa Valley while refinery products east of that line are produced from abroad. Because of price differentials there is some pressure on the Ottawa Valley line from foreign crude and products, and the cost-benefit implications of maintaining the marketing pattern established under the "national oil policy" in 1961 are under continuing review. In addition to price considerations, this policy review also involves assessments of the security of oil supply to eastern Canada in view of its dependence on foreign oil sources. Marketing studies in general relate to availability of oil and gas from various sources, price and changing patterns of demand.

Canada-U.S. Oil Relations

The United States is the sole export market for Canada's oil and gas and, consequently, the terms and conditions of this trade are of considerable importance, inasmuch as petroleum exports for the calendar year 1970 were valued at over $740 million and gas exports at $210 million. Among discussions held between the two countries regarding oil and gas were those which took place as part of the November 1970 meeting of the Canada-U.S. Committee on Trade and Economic Affairs. The continuing analyses under way on the allocation of oil and gas to the export market have regard not only to export opportunities but also to foreseeable domestic market requirements.

Environmental Concerns

The production and use of petroleum and natural gas involve many activities in which special care and high standards are required in order to minimize environmental hazards. In co-operation with the Department of Indian Affairs and Northern Development and the Department of the Environment, the Department of Energy, Mines and Resources is participating in an environmental field and research program relative to northern pipelines from which environmental standards are being developed as part of the country's northern pipeline policy. Other environmental concerns include those relating to the opening of the Athabasca tar sands and to the establishment of appropriate emission standards for the control of pollution from automobiles. Analyses of the impact of environmental hazards have regard to benefits and the costs of environmental control, the costs being considered part of the cost of energy.

International Interests

The Energy Development Sector began to study all aspects of the international oil and gas industries in order to

provide a world-wide perspective for policy recommendations concerning the Canadian oil and gas industries. Rapid developments on the international scene can have a marked effect on the domestic industry, and consequently we must understand current and expected trends in the international oil and gas economy. International events are also followed through participation in the work of such organizations as the Oil Committee of the Organization of Economic Cooperation and Development (O.E.C.D.) and the World Petroleum Congress.

Oil and Gas Policy Studies

Towards the end of the period under review, plans were completed for a major energy policy study which is designed to include an examination of existing oil and gas policies and recommendations as to new policy directions.

COAL

With respect to Canada's coal resources, the Energy Development Sector is responsible for developing sound policies and programs for the orderly, long-term use of this energy resource.

Such policies and programs cover a widely dispersed industry located in western Canada and the Maritimes and exhibiting a broad range of problems related to the extraction, preparation, transportation and marketing of coal. The strongly rising level of exports is adding an international dimension to Canadian planning for coal.

In this complex situation the co-ordinating role of the Energy Development Sector is of key and growing importance for ensuring that the full capabilities within the federal government are efficiently applied in rational programming for coal.

Departmental Committee on Coal

The Energy Development Sector has established the Departmental Advisory Committee on Coal for co-ordinating federal expertise and facilities related to coal. The committee also maintains liaison with the industry.

Support of Research and Development

In line with departmental policy the Energy Development Sector has resumed the issuing of grants, formerly administered by the Dominion Coal Board, to universities and other research centres for investigations related to coal resources. A sum of $100,000 was made available for this purpose in fiscal 1971-72 and, of this total, grants have already been issued in the amount of $75,160 to four research centres across Canada.

The Canadian Conference on Coal

The Sector takes a leading part in the organization of these annual conferences on coal in co-operation with the Coal Association of Canada and the Canadian Institute of Mining and Metallurgy. The 23rd Canadian Conference on Coal was held in Ottawa on September 19 to 22, 1971.

Co-operation with DEVCO

The Energy Development Sector has assisted the Cape Breton Development Corporation in developing a number of operational options for one of the Corporation's major collieries. These several options were evaluated for technical-economic feasibility by a committee appointed for that purpose and chaired by an officer of the Energy Development Sector. The findings and conclusions of the committee have been reported to the president and board of directors of the Corporation.

The MacBean Mine, Nova Scotia

In co-operation with the Department of Mines of Nova Scotia and Thorburn Mining Limited, the Energy Development Sector has participated in planning the orderly closure of the MacBean Mine. Federal financial assistance was obtained to cover operational losses during the remaining period of mine operation and to support certain reclamation work following closure. As also required under a Canada-Nova Scotia-Thorburn agreement of October 1971, the Province of Nova Scotia and Thorburn have assumed full responsibility for conducting the closure. The Department of Energy, Mines and Resources is overseeing federal financial aid and will also provide technical advice when requested.

The New Brunswick Coal Industry

The Sector has provided advice for improving techniques in surface mining and for a more detailed method for cost management and control.

The Western Coal Industry

The Energy Development Sector has continued to provide advice to coal exploration and mining companies. Consultation has included general discussion, covering the entire region, with coal consumers and companies considering the inclusion of coal in their operating sphere, and detailed evaluations from the exploration phase through mining, beneficiation and carbonization.

The Sector participated in the feasibility review of a research centre at Clover Bar in Edmonton.

Dominion Government Coal Blocks

The Sector has continued its involvement in the problems related to the development of the Dominion Government Coal Blocks in British Columbia and the evaluation of proposals put forward by prospective mining companies.

URANIUM AND NUCLEAR ENERGY

The uranium and nuclear energy industry in Canada embraces many activities, including exploration, mining, processing of ore, conversion of mill product to usable forms, fuel fabrication, reactor design and construction, reactor operation, and finally, to complete the cycle, the disposal of the spent fuel. With such a multi-faceted industry, it is not surprising that many federal departments and agencies participate in various ways to ensure that the industry is developed in an over-all manner beneficial to the country. The need for sound, flexible national policies and guidelines is further emphasized by the strategic importance of uranium, Canada's large uranium reserves, the long-term economic significance of uranium as a domestic energy source, and the future potential of uranium as a major export commodity.

The Energy Development Sector is engaged in the development and formulation of policy on uranium, nuclear energy and associated matters. Of particular interest are an assessment of international markets for uranium, a study of the feasibility of establishing a uranium-enrichment plant in Canada, the management of the uranium stockpiles that have been added to because of a recent agreement with Denison Mines Limited, and regulations limiting foreign ownership of the Canadian uranium industry.

International Markets for Uranium

Canada has more than 20 per cent of the Western World's proven reserves of uranium available at less than $10 per pound U_3O_8, and in 1970 this country produced about 20 per cent of the world's output, valued at more than $50 million. The industry is producing at a level considerably below its present capability, a situation which may exist for several years. The international market is growing rapidly, however, with the demand for uranium doubling every four or five years. Hence, in order to make long-term policies for the orderly growth of the uranium industry, it is important for the federal government to have an accurate assessment of the international supply-demand picture as well as up-to-date information on market price. Such information is being assembled by the staff in the Sector.

Uranium Enrichment

In-depth studies have been initiated on the question of the feasibility and desirability of establishing a uranium-enrichment plant in Canada. The subject was discussed during a mission led by the Minister to Japan. The mission to Japan served to acquaint officials from both private industry and government with the uranium requirements of that country and the attitude of the Japanese government and industry concerning possible co-operation with Canada in the enrichment field.

Uranium Stockpiles

During the period 1963-1970 the federal government spent $101 million for stockpiles of uranium, totalling 19 million pounds U_3O_8. A further $39 million will be spent in the years 1971-1974 accumulating 6.3 million pounds from a joint program with Denison Mines Limited, the largest Canadian producer of uranium. A joint stockpile program was initiated in 1971 to ensure the basic economic security of the Elliot Lake community where Denison is the major employer. A new Crown corporation, Uranium Canada, Limited, was incorporated in 1971 to act on the government's behalf in the acquisition and later disposal of the stockpile.

Foreign Ownership in the Canadian Uranium Industry

The question of foreign ownership of uranium mines in Canada is an important element in considerations being given to foreign ownership of Canadian industries in general. Canadian government policy limiting the proportion of foreign ownership in Canadian uranium production stipulates that owners of companies engaged in duly authorized exploration for uranium on March 2, 1970, and owners of producing companies will be permitted to retain their holdings. However, any sales of such holdings must be to Canadian residents until the total foreign ownership is reduced to 33 per cent. Also, no foreign investor, or group of associated foreign investors, will be allowed to retain more than 10 per cent ownership in a property. The Department has been given the task of co-ordinating the preparation of regulatory measures required to implement this policy.

RESOURCE MANAGEMENT AND CONSERVATION BRANCH

The Resource Management and Conservation Branch was established during the year, replacing the Resource Administration Division, in accordance with the Department's increasing responsibilities in the management of Canada's mineral resources.

This new Branch makes recommendations and provides advice on the handling of offshore mineral resources to government and private agencies. It administers the federal interests in mineral resources off the east and west coasts and in Hudson Bay and Hudson Strait, as well as those federally owned mineral rights in the provinces which become available for development. In doing so, the Branch designs, issues and administers various types of terminable offshore permits taking into account the special conditions of the offshore environment; establishes requirements concerning operations, production, conservation and pollution control; makes sure that companies carrying out offshore exploration comply with these requirements; and evaluates the mineral potential of offshore areas as a basis for management policy. The Branch also formulates policies and makes regulations concerning federally owned mineral rights in the provinces, and administers them.

Canada's submerged continental margin, which includes the continental shelf and the continental slope beyond, is the second-largest in the world, after that of the Soviet Union. It comprises about two million square miles, which is more than half as large as Canada's entire land area. Of this the largest part lies off the east coast, about 400 thousand square miles lie in Hudson Bay and Hudson Strait, 50 thousand square miles lie off the west coast, and the remainder is in the high Arctic, in the Beaufort Sea and Arctic Archipelago regions.

Although not all of Canada's offshore areas are prospective for mineral resources, it has been estimated that as much as half of Canada's remaining recoverable reserves of oil and gas are located beneath Canada's submerged continental margins, particularly beneath that off the east coast and the north. The petroleum industry, which for many years has concentrated its exploratory efforts in Canada's Prairie Provinces, is now shifting its attention to the offshore and to the Arctic, both of which frontier regions are now experiencing an unprecedented wave of exploration. The potential for offshore mineral resources other than oil and gas is also promising. However, in Canada as in other regions, offshore mining is not as far advanced as the offshore oil and gas industry.

At the end of the fiscal year 1971, Canada Oil and Gas Permits covered about half the area of the Canadian submerged continental margin. These offshore permits are issued and administered under the *Canada Oil and Gas Land Regulations,* which are now undergoing extensive revision.

Operational Controls

During the fiscal year, a new bill amending the *Oil and Gas Production and Conservation Act* was passed which extends comprehensive statutory authority governing operation, production and conservation matters to the offshore. The Act now provides for wide statutory authority over all offshore oil and gas activities, covering exploration and drilling for, and the production, conservation, storage, transmission, distribution, measurement, processing, and other handling, of oil and gas produced offshore. Although the primary objective is the protection of human life, the prevention of pollution of the marine environment

and the conservation of oil and gas resources, those aspects concerned with production matters are also important. Among them are requirements for pooling and unitization of productive areas, with production therefrom carried out in accordance with optimum engineering practice, so that costs are kept as low as possible to help make the oil and gas produced competitive in world markets.

The Department has the authority under the *Oil and Gas Production and Conservation Act* to shut down operations in the interests of safety or pollution prevention and to prohibit their resumption until adequate remedial steps have been taken. The Department, through the Resource Management and Conservation Branch, is even empowered to take over management and control of an operation at the operator's cost if, in the opinion of Branch officials, satisfactory steps are not being taken to remedy the situation. Penalties are provided for contravening the Act.

In brief, operators are required to: submit notices of proposed programs; provide information and appropriate materials on a current basis; assist in the carrying out of inspections by authorized officials; furnish comprehensive technical reports; and support claims for refunds of guaranty deposits with certified statements of expenditures. Thus, all parties carrying out offshore work must not only obtain prior authorization before the commencement of each program of operations, they must submit reports on these operations on a current basis, and they must submit information and materials obtained as a result of the work. The large volume of offshore materials and technical information, including well logs, cores, and cuttings, submitted under the Canadian regulations is then processed, curated and stored to ensure its preservation. Upon the expiration of appropriate periods of confidentiality the materials and information are made available to the public in a proper form and manner.

Federal authorities maintain control over offshore activities by means of a system that provides a number of safeguards. Before undertaking an offshore exploration program, a company must first submit for approval by the Branch a comprehensive *Offshore Program Notice* describing the proposed work in detail, for example, each seismic survey. Drilling an offshore well involves special requirements. A well cannot be drilled until the authorities have approved an *Offshore Drilling Notice* setting out in detail the company's proposed drilling plans. The actual drilling is then subject to supervision by Branch officers. In this regard, officers inspect each drilling location in order to ensure that federal requirements are being met. When a well has reached total depth, Branch approval must be obtained for the manner in which it is to be completed, suspended or abandoned.

In recognition of the special nature of the vulnerable offshore environment, the Branch maintains a system of coordination between industry and governmental agencies involved in the utilization of the offshore. Its primary purpose is to ensure that the special requirements of governmental agencies with offshore responsibilities are made known to industry and that industry in turn meets these requirements. Several agencies in addition to the Department of Energy, Mines and Resources have practical responsibilities related to the offshore, and each of these agencies receives advance notice of proposed offshore activities so as to allow time for appropriate action. The Department of the Environment receives 90 days notice; the Department of Transport 60 days notice; the Department of National Defence 45 days notice.

East Coast Regional Office

During the fiscal year, supervision and control of all oil and gas activities off the east coast, particularly exploratory drilling, were carried out under the Oil and Gas Production and Conservation Act, using the Branch's new regional office in Dartmouth, N.S., as a base of operations. A laboratory associated with this office was opened in 1970 to handle the cores, cuttings and other materials from wells drilled off Canada's east coast and in the Hudson Bay and Hudson Strait regions. These materials are now being received, processed and curated at this laboratory, where they are made available for examination, after the expiration of associated confidential periods, to interested scientists. By the end of the fiscal year, plans were being finalized to construct a $100,000 addition to this office-laboratory building, in order to accommodate a team of subsurface experts affiliated with the Geological Survey of Canada who will carry out micropaleontological, palynological, sedimentological and stratigraphic analyses of cores and cuttings from east coast offshore wells. The results of these studies will assist the Branch in fulfilling its responsibilities.

In Canada's offshore regions it is particularly important that well materials are properly handled, processed, curated and analysed, since they have been obtained at great cost, and are often the only tangible asset remaining after the drilling of an unsuccessful well. In particular, their valuable microfossil and spore content, which is vital for age-dating, stratigraphic correlation and interpretation of sedimentary environments, would soon be depleted

and lost permanently if not properly extracted and curated.

Canada is one of the few nations in the world in which industry is required to submit to the government complete suites of rocks, fossils and mechanical logs obtained in drilling for oil and gas. These materials provide an important record of our sedimentary basins, which can be referred to time and again in the never-ending search for strategic fossil fuels and other minerals. The results of the studies carried out in the new laboratory will not only assist the Resource Management and Conservation Branch in fulfilling its responsibilities as regards the development and conservation of offshore mineral resources, they will provide a regional biostratigraphic and sedimentological framework for Canada's Atlantic continental margin, and the dissemination of such information will help stimulate and sustain the optimum development of Canada's offshore mineral resource potential.

Offshore Activity - 1970

During 1970, oil companies spent $37 million in the evaluation of offshore Canada Oil and Gas Permits administered by the Branch, which constitutes an increase of $15 million over 1969. Of this amount, $13 million was expended for geological and geophysical surveys, and $24 million for exploratory drilling. Cumulative industry expenditures in Canada's offshore to the end of 1970 (excepting the high Arctic) reached $117 million, including $58 million for geology and geophysics and $59 million for drilling. During 1970, the Branch approved 80 separate offshore exploration programs, which were subsequently monitored by Branch officers to ensure that they were carried out in accordance with federal requirements.

Highlights of 1970 industry activity included:

(1)Continuation of Shell's exploratory drilling program on the Scotian Shelf. The semi-submersible offshore drilling unit SEDNETH 1, which commenced this program in September 1969, was joined in May 1970, by a second and even larger semi-submersible unit, the SEDCO H, which was constructed in Halifax Shipyards by Hawker Siddeley Canada Ltd. for Southeastern Commonwealth Drilling Limited at a cost of $13 million. Twelve wells were completed and subsequently plugged and abandoned during 1970 by these two rigs, and drilling was progressing at two additional sites at the end of 1970. No commercial discoveries were made during the year, although significant showings of oil and gas were encountered in a number of wells.

(2)Completion of construction of a second large semi-submersible offshore drilling unit by Halifax Shipyards, the SEDCO I, in December 1970. This unit, which is identical to the SEDCO H, was contracted to Amoco and Imperial for a continuous drilling program on the Grand Banks that was to commence in April 1971.

(3)Start of construction in Halifax Shipyards of a third offshore drilling unit, the SEDCO J, identical to the H and I units, for completion in late 1972 at which time it will be contracted to Mobil Oil Canada for a drilling program on that company's permits off the east coast.

(4)Drilling of two exploratory wells in the Gulf of St. Lawrence east of Prince Edward Island by Hudson's Bay Oil and Gas Company and Petrofina Canada, using the WODECO II drilling barge, a much smaller unit than the SEDNETH and SEDCO units.

(5)Drilling of two onshore wells in the Gulf of St. Lawrence region on Anticosti Island and on Brion Island. These wells were immediately adjacent to offshore Canada Oil and Gas Permits in the Gulf and contributed significantly to the evaluation of these permits.

Canada Oil and Gas Permits

The Branch issued 489 Canada Oil and Gas Permits covering 28.3 million acres during the fiscal year 1970-71, all off the east coast. This brought the number of offshore Canada Oil and Gas Permits administered by the Branch to 5,909 as of March 31, 1971, covering 413.7 million acres as follows:

East coast ..... 3,906 permits - 287,359,292 acres
West coast ..... 207 permits - 13,844,284 acres
Hudson Bay - Hudson Strait 1,796 permits - 112, 547,345 acres

The total revenues received during the fiscal year 1970-71 from offshore permits, including permit fees, transfer fees, forfeitures, exploratory licences and maps, amounted to $269,448.99, most of which was derived from permit fees.

Mineral Claims

Offshore mineral claims for mineral rights other than oil and gas rights are recorded under the *Canada Mining Regulations.* No offshore mineral claims were recorded during the fiscal year. The total number of mineral claims in effect was 206, as follows: East coast: 82; West coast: 42; Hudson Bay: 82. Total revenues received from prospecting licences during the fiscal year 1970-71 amounted to $281.62.

Federally-owned Mineral Rights in the Provinces

During the fiscal year 1970-71, 15 oil and gas leases were issued (10 in Alberta, 5 in Manitoba) bringing the total number of federal oil and gas leases in the provinces to 216, as follows: 113 in Alberta; 62 in Saskatchewan; 37 in Manitoba; 4 in Ontario. In addition, two leases for minerals other than oil and gas are held in Ontario. On March 31, 1971, 69 oil and/or gas leases were productive as follows: 37 in Alberta; 22 in Saskatchewan; 9 in Manitoba, and 1 in Ontario. The total revenues received during the fiscal year 1970-71 from oil and gas leases, including royalties, lease sale bonuses, rentals, extension fees, lease fees and assignment fees, amounted to $285,430.22, most of which was derived from royalties.

Mineral Development Sector

MINERAL RESOURCES BRANCH

The Mineral Resources Branch carries out a continuing review of the role of minerals in the Canadian economy. The Branch advises government planners and policy-makers on ways and means to utilize minerals in a manner that will contribute to the economic and social well-being of the Canadian people while maintaining a progressive industry.

Activities carried out in the Branch may be regional, national or international. The interrelationships between exploration, processing, development, transportation, marketing receive constant attention, owing to their effect on the state of the mineral industry in its world setting. Comprehensive studies on minerals are carried out that include: the effects on regions; developments in the mineral industry; analysis of government policies affecting the mineral industry, including taxation and legislation; harmonization in the development of multiple resources; and developments in foreign mineral industries.

The Branch comprises four divisions, namely, Minerals and Metals, Resource Development, Mineral Economics Research, and Administration.

Review of Governmental Policies Affecting Minerals

There is increasing public interest in the potential contribution of mineral resources to the well-being of Canadians. Also, expanding foreign and domestic demands are placing greater pressures on Canada's finite mineral and related resources. Consequently, a comprehensive review of existing policies affecting minerals and how they contribute to or complement other economic and social policies was initiated. In general, the aim is to increase the economic and social benefits to Canadians from the industry. Specifically, it includes such matters as ensuring a mineral supply for national needs; preparing an inventory of Canadian mineral-resource potential; improving mineral conservation and use; improving returns from exportable mineral surpluses and developing practices for efficient multiple resource use.

Branch members seek to identify the objectives of a minerals policy and the needs for inter-agency collaboration. Plans are afoot to increase the staff engaged in forecasting so that the consequences of alternative policy options can be better assessed.

Taxation and Foreign Ownership

The government continually consults the Branch on the taxation of the mineral industry.

The Government Task Force on Foreign Ownership requested the Branch to participate in that part of its study dealing with the resource-based industries. Analyses were made of the foreign-ownership policies and economic-development strategies of countries buying or selling minerals. In addition, the Branch keeps an eye on the sources and availability of capital for the Canadian mineral industry and on Canadian ability to supply minerals at different

levels of processing. The Branch produced a study on laws covering disclosure requirements of mineral companies operating under various jurisdictions in Canada. These studies will contribute to the review of Canadian minerals policy as well as to an improved understanding of foreign ownership.

Environmental Quality

The effects of mining and processing on the environment led to a concern about measures to deal with this matter. The basic challenge is to harmonize development with environmental-quality objectives. A number of inquiries were made, including preliminary studies of the Foothills coal region and of mine health and safety. The Branch also made an inventory of the environmental impact of energy production and exploration as a contribution to the energy-policy study.

Social Development

Although mineral resources contribute to social development by creating jobs and often entire communities in the remote areas of the country, there may also be social problems for communities when a mine ceases operations. The Branch administers the Emergency Gold Mining Assistance Act (EGMAA), which was designed to minimize the social and economic hardships in a number of communities dependent on gold mining, which is rapidly declining.

An amendment to the Act in 1963 contained a restriction limiting eligibility for assistance, in the case of lode gold mines commencing production after June 30, 1965, to those providing direct economic support to an existing mining community. A gold mine is deemed to provide such support if more than 50 per cent of the persons employed at the mine reside in the established mining communities listed in a schedule to the Act.

Further amendments to the Act which received Royal Assent on February 11, 1971, resulted in the following changes:

1. The application of the Act was extended to June 30, 1973.
2. A gold mine, other than a placer mine, had to be in reasonable commercial production in the month immediately preceding August 7, 1970.
3. A gold mine that was not a placer mine was required to agree in writing to:
   a) conduct all future hiring through Canada Manpower Centres,
   b) give notice of a mine closure at least four months prior to cessation of operations,
   c) retain, immediately following notice of closure, the Manpower Consultative Service of the Department of Manpower and Immigration to assist in the placement of employees as they are laid off.

The number of lode gold mines receiving assistance under the Act has declined from 87 in 1948 to 30 in 1970.

The amount of assistance payable to an operator depends on the amount by which the average of production exceeds $26.50 per ounce. When calculated on the basis of all eligible ounces produced, the maximum assistance payable amounts to $10.27 per ounce.

The amounts paid to gold mine operators to March 31, 1971, for the years 1948 to 1970 inclusive totalled $288,592,320.47 on a production of 60,240,260.105 fine ounces of gold.

Figures for the calendar year 1970 are not yet complete, but the total expectation is approximately $14 million.

Regional Development and Mineral-Based Activities

Mineral-resources activities may help significantly to reduce regional economic disparities, both in terms of income and employment. Indeed, it is becoming increasingly apparent that proper mineral-resource-management strategies can provide the basis for much self-sustained regional economic growth. One major aspect of such development is the diversification of the regional economic base through development and further processing.

The Branch co-operates with many other federal and provincial agencies in this area. Projects include: the analysis of further-processing opportunities for Canadian metal production with forecasts for the next five years; a *Northwest Canada Resource Transportation Study* in co-operation with the Department of Transport to examine the extension of transportation networks in northern British Columbia, Yukon and Northwest Territories; a *Study on the Potential Outlook for Bulk Commodity Movement Through Various Canadian Ports* in co-operation with the National Harbours Board; a mineral-development program for New Brunswick in co-operation with both the province and the Department of Regional Economic Expansion—to date, this program has resulted in potash and salt deposit discoveries; a similar program for New-

foundland is now being negotiated; an evaluation of the economic mineral potential of Manitoba in co-operation with the province; and preparation of a study of mining legislation and land-use regulations in the north.

Foreign Aid and Research Grants

The Branch, on behalf of the Department, contributes to the Canadian International Development Agency's foreign aid. It provides departmental co-ordination through advice and/or evaluations on proposals for capital projects in other countries and in the selection of experts for foreign-aid projects abroad. For example, an assessment of the economic potential of foreign deposits was undertaken by the Branch.

The Department, through the Branch co-ordinator, made recommendations on applications to the Canadian International Development Agency for technical training of foreign students. These programs were sponsored through the various regional plans of the Agency and through the United Nations. Practical training was arranged partly within the Department of Energy, Mines and Resources and also in private industry, provincial government departments and university graduate schools.

The Branch established a modest grants program to encourage and support mineral economic research in Canada, including exploration, mining, and mineral processing and product distribution. However, applications are also invited from a wide range of other social-science disciplines (sociology, law, political science, social geography) that may contribute to a better understanding of the principles of mineral-resource supply and demand, or of mineral-resource management. Both theoretical and practical studies are of interest, but special consideration will be given to those dealing with policy problems confronting Canadian mineral-resource management and development. Studies may focus on a commodity or a region.

Mineral-industry Analysis

Research in this area provides much of the factual and analytical foundation for many of the other activities in the Branch and for the advice and recommendations relating to the economic performance and management of the mineral industry. In general, economic analysis is conducted on such factors as resource-supply adequacy, exploration, mining, smelting, refining, uses, prices, trade, tariffs, foreign developments and other aspects which may vary among mineral commodities. Forecasts play a vital role, especially since mineral-commodity and industry activities have a diverse set of policy implications on many of the national issues of concern to the Branch. This work frequently involves the Branch in international meetings. For example, the Department is represented through the Branch at the OECD International Lead-Zinc Study Group, the European Nuclear Energy Agency (ENEA), OECD Joint Ad-hoc Group Energy Committee and Industry Committee on Coking, and the International Tin Agreement meetings.

The following studies are characteristic of the many facets of the mineral industry studied: short-term forecasts of the production of Canada's major metals and industrial minerals; a review of problems associated with the world oversupply of sulphur and its relation to Canadian production and future pollution-abatement measures; commodity forecasting techniques (demand and exports) illustrated by zinc; the examination of a number of world supply-and-demand problems in copper, coal, nickel, potash, in close co-operation with the Department of Industry, Trade and Commerce; a study of the Canadian cement industry; and the production of a potash trade map to illustrate world production and trade in this vital fertilizer material.

EXPLOSIVES DIVISION

Following an alarming number of serious accidents in the early 1900s, it was evident that some control over the explosives industry was necessary to safeguard both the industry's workers and the public. As a result, the Explosives Act was introduced in 1911 and passed by Parliament in 1914. Proclamation was delayed by World War I until 1920. The Explosives Division of the then Department of Mines had been formed the previous year to administer the Act.

The immediate and continuing acceptance by the industry of the imposed controls has made the explosives industry one of the safest in Canada. This is clearly shown by the significant reduction in accidents during the intervening years. In the four years prior to the introduction of the Act, in manufacture alone, some 42 fatalities occurred during the production of an estimated 20,000 tons of explosives; in contrast, in the past four years there has been but a single fatality in the production of over 655,000 tons.

The primary objective of the Division is to protect the employees of explosives factories and all those who regularly or even occasionally handle store, transport and use explosives, and by so doing directly safeguard the public at large. An explosive includes any substance that is made, manufactured, or used to produce a violent effect by explosion or a pyrotechnic effect. The Division therefore is responsible for all factories that produce commercial blasting explosives, military explosives, blasting accessories, gunpowder, smokeless powders and percussion primers, ammunition, fireworks and other pyrotechnics, and for the quality and safety of their products. This responsibility extends also to the road transportation of these items and to their storage and importation.

Control is exercised by a system of licences, permits and sales records supported by inspections by members of the Division and by the Royal Canadian Mounted Police. All licences and permits are issued from the Ottawa office.

A general quickening in construction and mining activity during the year was reflected in an increased office and inspection workload with which the Division was just able to cope. The number of factory licences continued to increase as expected, reaching a total of 55 by year end, mainly due to the expansion of on-site slurry or water-gel manufacturing facilities at additional open-pit mines. However, two factories manufacturing sporting ammunition ceased operations during the year. Similarly, the number of licences issued for the storage of blasting explosives in support of construction projects, road building, seismic exploration, pipeline laying, erection of transmission towers, forestry and like operations rose to more than 1,200. Licences issued to vendors of explosives remained relatively constant at about 400. In addition, more than 400 explosive transportation permits were issued to explosives distributors and owners of other commercial vehicles for the haulage of explosives in support of these activities.

A new hobby for youth — model rocketry — has been rapidly gaining popularity. By year end, 39 licences had been issued to hobby shops across Canada to permit the sale of model rocket engines to individuals licensed as firing supervisors by the Canadian Association of Rocketry, a division of the Youth Science Foundation of Canada. The small rocket engines used in this sport consist of a propellant explosive, and although relatively innocuous in themselves, even if involved in a fire, can accelerate to the speed of a bullet shortly after launch and can push a rocket to heights in excess of 2,000 feet. These properties make them a hazard to aircraft or to the public if misused.

Except for the one fatality mentioned previously which occurred during the manufacture of a military explosive, the year has been exceptionally accident-free. Even though many incidents were reported during the manufacture, handling, storage and transportation of explosives, few injuries were sustained and these were all minor, and the over-all property damage was minimal. Since the actual use of explosives is beyond the purview of the Explosives Act, data on explosives accidents occurring under such circumstances are not included.

Members of the Explosives Division promote safety programs and regularly meet with members of industry, federal and provincial government agencies, municipal authorities and other groups involved with the handling of explosives. The Division also has available for distribution safety literature on the storage, handling and transportation of explosives.

A separate, more detailed report of the activities of the Explosives Division is published periodically.

Science and Technology Sector

SURVEYS AND MAPPING BRANCH

The past fiscal year has seen satisfying progress in the Surveys and Mapping Branch's efforts to provide maps and surveys for the development, administration and protection of Canada. Two projects in particular, because of their vast scope and impact, caught the attention of the general public. These were (a) the air photography of the prairies which was taken during the first two weeks in August in support of the LIFT (Lower Inventories for Tomorrow) Program; and (b) the start of the detailed mapping of the Mackenzie River valley, the so-called pipeline corridor. Further details of these and the more routine programs of the Branch are given in the directorate reports that follow.

GEODETIC SURVEY OF CANADA

Twenty-two field parties established horizontal and vertical control to extend and densify the existing national control-survey framework and to provide control for the national mapping program. In addition, the Survey continued its activities in investigational work.

The extension and densification of the first-order horizontal-control framework was carried out in Yukon and Northwest Territories and four provinces. In the Territories the aerodist network was extended westward from the Yukon-Northwest Territories boundary between the Porcupine River and the Arctic coast; and eastward, between Great Bear Lake and the Arctic coast, to connect with the existing Yellowknife Coppermine control network. This project covered 91,200 square miles and provided horizontal mapping control for three hundred and eighteen 1:50,000 map sheets. In Alberta a network was established to control and co-ordinate municipal surveys in Fairview, Grimshaw and Peace River. In Ontario the control network in southwestern Ontario, along the north shore of Lake Erie, was completed to Dunnville, and a small network was established to control municipal surveys in Sault Ste. Marie. In Quebec, in co-operation with the Quebec Department of Lands and Forests, the densification of the existing control framework was continued in the area between Quebec City and Trois Rivières. In Nova Scotia the central loop of control was completed between Annapolis Royal and Liverpool and a new network started from Halifax toward the Strait of Canso.

First-order levelling was carried out in five provinces. In British Columbia a line was extended from Mica Creek down to the Columbia River to Needles on the Arrow Lakes; in the course of this work a reciprocal water-crossing of 1.6 miles was made between Shelter Bay and Galena, the longest passage of precise levels across water made by the Geodetic Survey. The Trans-Canada level line was extended eastward from Sault Ste. Marie to Arnprior, thus continuing this major project which was started in 1966 and was to be completed in 1971. In Quebec, levelling of high precision, using the metric system, was continued in the International Great Lakes Datum re-evaluation program. The line was extended eastward from Quebec City to Father Point; a portion of this line also forms part of the Trans-Canada level line. In the Maritimes, lines of levels were run from Glenholme, Nova Scotia, to Dorchester, New Brunswick, and from Truro,

Nova Scotia, to Waverley. First-order vertical-control grids were established in Halifax-Dartmouth and Montreal and in the southeast part of the National Capital area. A small party checked the stability of 81 Hydrographic Service water-gauge sites between Father Point, Quebec, and Thunder Bay, Ontario. Eighteen deep benchmarks were established near gauge sites where the stability of normal benchmarks was questionable.

Three astronomic parties established eleven Laplace azimuth stations, two sets of intervisible Laplace azimuth stations and twelve plumb-line-deflection stations at various locations throughout the country. The precise astronomic position of the satellite-triangulation station at Cambridge Bay, N.W.T., was also determined. The joint Canada-United States satellite-triangulation program was resumed in October. A combined Canadian-American team manned the station at Whitehorse, and a similar team, including surveyors from the Canadian Armed Forces, manned the station at Cambridge Bay.

The assistance to provincial and municipal authorities in establishing rectangular co-ordinate survey systems was continued at a reduced level. Traverses were run at Hay River to control legal surveys and town-plan mapping. In southern Ontario the co-operative program with the Ontario Department of Highways was completed with the establishment of second-order traverses control in the Windsor-Leamington-Ridgetown area. A second-order municipal control grid was established in Sault Ste. Marie and the control grid in Halifax was strengthened and densified.

A helicopter-supported party established horizontal control for 1:50,000 mapping in a large area of the District of Keewatin between the 60th parallel and Baker Lake. Vertical and horizontal control for 1:25,000 mapping was established in the area of the new Ste. Scholastique airport in Quebec.

Research was carried out on methods of integrating existing low-order horizontal and vertical control surveys into the national networks, and an investigation into gyrotheodolites was carried out. The latter proved particularly interesting when it was discovered that, with a special electronic readout system designed and built in the Branch, azimuths can be obtained that are virtually as accurate as first-order astronomic observations.

LEGAL SURVEYS

The Legal Surveys Division continued its statutory general management and technical control of all legal surveys in Indian Reserves, National Parks and the Territories.

The Division had 18 survey parties in the field and, in addition, contracted work to 25 survey firms in private practice to complete as many as possible of the projects required for the federal government. They worked on 94 projects in Indian Reserves in all of the provinces except Newfoundland and Prince Edward Island, and 23 projects in National Parks. In addition, technical instructions were issued for 151 surveyors on Crown Canada Lands for provincial and private agencies.

In the Territories, co-ordinate control work was carried out at Whitehorse and Yellowknife, and 30 legal surveys were made at other locations throughout the north.

Two federally appointed commissions, chaired by the Surveyor General of Canada Lands, were involved in the survey and maintenance of provincial boundaries. The Manitoba-Saskatchewan Boundary Commission continued the resurvey of the southerly 240 miles of that boundary. This year's work included the survey of 43.6 miles of boundary and clearing of a further 18 miles through heavily wooded country. The British Columbia-Yukon and Northwest Territories Boundary Commission reviewed the use of defoliant spray on the boundary and decided that no further maintenance work should be carried out for the year 1971-72.

TOPOGRAPHIC SURVEY OF CANADA

Photogrammetry Division

During the past year the Division forwarded for reproduction 513 National Topographic Series maps. This total was comprised of 263 new maps and 250 revised maps. Twenty-eight field parties carried out field-completion work, mainly on revision map sheets. In addition, two engineering field parties carried out horizontal and vertical quality checks on a number of 1:50,000 maps.

The new mapping highlight of the year was the compilation of 120 maps at the scale of 1:50,000 in the Mackenzie River area, commonly referred to as the pipeline corridor. These maps were completed to an enhanced advance-print stage (i.e. suitable for monochrome reproduction and distribution) during a six-month period commencing December 1, 1970.

Photomaps were produced to meet the needs of northern development, geological exploration and provincial map-

ping. The Division produced 425 sheets, ranging in scale from 1:5,000 to 1:250,000. The development of the Gestalt Orthophoto System in Vancouver during the year has made posible 1:50,000 photomapping of more rugged areas than heretofore possible.

Consultant services on photogrammetric mapping were supplied to other federal agencies on a steadily increasing scale. These services included providing technical advice, identifying the needs, writing technical specifications, and inspecting and monitoring contracts awarded to the aerial-survey industry.

The Research and Development Section initiated two major projects that are likely to have a profound impact on the mapping of the country. The first, carried out in co-operation with the Institute for Photogrammetry of the University of Stuttgart, West Germany, is the development and testing of a new method of aerotriangulation and analytical adjustment for photogrammetric blocks of unlimited size. This development will further reduce the need for ground survey points. The second project is the partial automation of the map-compilation process. In addition, techniques in photomapping were improved, research in the use of high-altitude photographs for topographical mapping was continued, and a photogrammetric test area was created near Ottawa.

Aerial Photography Division

During the period under review, 8,295 requisitions requesting photographic work were forwarded to the Air Photo Production Unit for processing. The Ottawa office issued 7,283 requisitions, the Calgary office 894, and the Canada Centre for Remote Sensing (established July 1) issued 118 requisitions. These requisitions requested contact prints, enlargements, glass and film diapositives, transparencies, index maps, film processing and specialized photographic products totalling 764,683 black-and-white products, 23,615 color products, for a total of 788,298 products.

The Ottawa office has on file 3,491,400 photographs, and the Calgary office has 594,926 file copies. The Ottawa office has also started to file negative and positive film generated by the Canada Centre for Remote Sensing.

The National Air Photo Library was used as a reference library by various members of the Department, private industry, educational institutions and the general public. To improve these services, the Library is planning to expand its public viewing facilities and photo-interpretation equipment.

MAP PRODUCTION DIRECTORATE

Aeronautical Charts Division

In 1971, the Aeronautical Charts Division produced 50 different map series and flight-information publications.

A highlight of this year is the conversion from the National Topographic System format of 1:1,000,000 World Aeronautical Charts, which covered Canada with 68 sheets, to a new format. The new format will provide coverage of Canada by 19 sheets, using larger paper and printing maps on the front as well as the back of the chart. Seven of the new-format charts have been published, and it is expected that completion of the conversion will be achieved in 1972.

Another new project is the production of 60 military shaded-relief charts, at 1:250,000 scale, in co-operation with the Mapping and Charting Establishment of the Department of National Defence.

In 1971, the Division supported the London-Victoria Air Race by providing, at very short notice, the revision of 49 aeronautical charts at a scale of 1:500,000 covering the Canadian part of the race.

A new Radar Digital Display System for air-traffic control, which is being developed by the Ministry of Transport, is being supported by the Division. A total of 245 colored video charts has been produced for this system which will be experimentally operational at Moncton by the beginning of 1972. All charts are subject to the 28-day revision cycle established for radio-navigation publications. To cope with the large workload created by this project, programs have been written to use the Computer Graphics System, which is now being developed by the Branch.

A chart has been developed for the purpose of designating and evaluating potential STOL operations between Ottawa and Montreal.

During 1971, 16 more controller charts were taken into production for a total of 64, and 25 more black-and-white video charts to raise the total of this type of presentation to 91.

A new publication to support the visual navigation charts, called the *VFR* (Visual Flying Rules) *Supplement,* has been designed and a prototype has been completed. Production of this publication was to start early in 1972.

Automated Cartography

Development continued in applying computer technology to cartography. A Kingmatic Automatic Plotter was delivered and passed acceptance tests early in the year. Software and cartographic procedures were developed and tested with a view to being operational for production work in 1972. Two pilot projects were completed during the year in order to prove the operation of equipment and the function of software. One of the pilot projects was a 1:50,000 National Topographic Series map which was presented at the Commonwealth Conference at Cambridge, England, in August. This map was received with great interest, and it was acknowledged that Canada is one of the world leaders in this field. New equipment purchased late in the year included two more digitizing stations and a Storage Tube Display Terminal. The digitizing stations will be assigned to production work, while the display terminal will be initially used for experimental work in co-operation with Waterloo University.

Cartography Division

One of the principal tasks of this Division is the drafting and completion of map manuscripts produced by the Topographical Survey Directorate. During the past year, drafting was completed for 45 maps at 1:25,000 scale, 316 maps at 1:50,000 scale and 10 maps at 1:250,000 scale.

Another function is the production of small-scale geographical maps. In the International Map of the World (IMW) series, 19 maps have been printed, and a further 12 maps are in production. A major revision of the popular map of Canada at 100 miles to one inch was published during the year.

The Division also provided cartographic services to other departments. Such services included a revision of a map of the highways of Canada and northern United States, an electoral map of the Northwest Territories, five maps for inclusion in the booklet covering the royal tour of British Columbia, and a map of the world showing Canada's role in the production of potash.

Geography Division

Forty per cent of *The National Atlas of Canada* and *L'Atlas National du Canada* had either been printed as loose sheets or was in color proof or plating by the end of the fiscal year. The remaining material was in various stages, with approximately one year's work required for completion. A special map showing density of population of Canada for 1961, derived directly from the National Atlas, was published in French and English versions.

A series of 91 maps at 1:500,000 covering the country, showing the 1966 hierarchy of census areas, including enumeration areas, was brought to completion. The maps are primarily for Branch use, but are available on plastic or as ozalid prints to the public.

Map Reproduction Division

The map printing for the past year amounted to a total of 39,472,679 impressions. These included 979 topographical maps, 518 aeronautical charts, 36 general maps, 648 departmental maps other than the above, and 277 maps and charts for other departments, being a total of 2,458 maps and charts printed.

TECHNICAL INFORMATION AND SALES OFFICE

Toponymy and Libraries Division

During the 1970-71 fiscal year, the Division, in support of the Canadian Permanent Committee on Geographical Names, investigated 34,768 names, of which 7,281 were new decisions. Geographic nomenclature was checked and verified for 572 new maps, 494 submissions. Various geological maps and tourist travel maps were examined and errors drawn to the attention of the producers. The staff answered 730 inquiries which entailed a significant amount of investigation and research. Provisional editions of the Yukon Territory gazetteer and Northwest Territories gazetteer were produced in 1971. The field-research program in Prince Edward Island was completed, and a revised list of ice features incorporating 223 additions and corrections to *Special Supplement No. 1-A List of Glaciological Features in Canada* was prepared.

The Book Library and Map Library both continued their service to the Branch. They also continued to provide other government agencies and the general public with surveying and mapping information.

Branch Publications Unit

During the fiscal year under review, the Publications Unit edited and produced publications in topography, photogrammetry, geodesy, cartography and geography.

The publication output consisted of 10 technical reports; 10 reprints from professional journals, the originating authors being members of the Branch; 9 issues of the

monthly in-house publication *The Surveys and Mapping News;* 4 special reports authored by consultants to the Branch; 1 seminar proceedings from the University of New Brunswick; 3 workshop study reports authored by members of technical workshops held in the Branch; and the production and editing of 3 technical papers for presentation at Branch technical seminars.

Map Distribution Office

The Map Distribution Office continued its normal work of issuing maps, charts and flight-information documents to government departments and selling them to the general public. An interesting comparison between the year of this report and five years ago is given in the following table:

	1965-66	*1970-71*
Total distribution of maps and charts	3,200,000	3,344,000
Sales to the public	820,000	1,828,000
Revenue from sales	$260,000	$539,000
Total orders filled	54,000	84,000
Sheets received from presses	14,500,000	18,700,000
Subscribers to *Canada Air Pilot*	6,800	9,600
Subscribers to *Enroute Charts*	4,100	5,800
Dealerships in operation		
Map dealers	175	345
Air-chart dealers	150	246

SPECIAL BRANCH FUNCTIONS

Foreign Aid Activities

The Canadian International Development Agency (CIDA) has continued to call on the Surveys and Mapping Branch for assistance in evaluation of work done on capital projects abroad and for advice and assistance in meeting requests for training.

Work on two projects, a *Land Valuation Index* for Barbados and semi-controlled mosaics for part of the coastal area of Kenya, was completed during the year. Further progress was made in topographical mapping projects in Tanzania, Kenya, Guyana and Trinidad and Tobago. A feasibility study for a project proposed for Ghana was also undertaken and completed.

Familiarization tours and on-the-job technician training have been provided for survey staff from Guyana, Morocco, Ceylon, Kenya, Jamaica and India during the year. A twelve-week summer course was provided for 24 undergraduate students from 8 different countries attending Canadian institutes of technology and universities under the sponsorship of CIDA and five others were attached to the Branch to gain experience during the summer months.

International Boundary Commission

The Commission continued the annual field maintenance required for the effective definition and marking of the 5,525 miles of boundary dividing Canada and the United States. Inspections were carried out on various parts of the line, and maintenance operations were undertaken in three areas by the Canadian Section of the Commission.

The Commissioners for Canada and the United States made joint inspections along the line and inspected the work of field parties on the boundary between Manitoba and North Dakota, Quebec and New York, and Quebec and Vermont. The Commissioners, together with federal and provincial dignitaries, attended a ceremony to unveil a plaque commemorating the establishment of a monument on the international boundary marking the completion of the survey of the Manitoba-Saskatchewan boundary in Manitoba's Centennial Year.

A Canadian field party working on the Manitoba section of the international boundary erected the above-noted commemorative monument, inspected 92 additional monuments, 17 of which required repairs, and treated with herbicides 89 miles of 20-foot boundary vista.

A second Canadian field party, working on the Ontario-Minnesota boundary, continued resurvey operations along the Rainy River, to re-establish many reference monuments lost through erosion, and to improve the overall accuracy of the original boundary survey in that area. Later in the season this field party transferred to the Quebec-Vermont boundary where a similar resurvey operation was initiated to replace and repair damaged monuments and to improve the geographic data on boundary monuments, which are presently based on surveys completed in 1907.

In addition, field officers of the Canadian Section completed the annual position checks on buoys defining the international boundary through the fishing grounds at the western end of Lake Erie.

INTERDEPARTMENTAL COMMITTEE ON AIR SURVEYS

In 1970 a modern jet aircraft was used for the first time on ICAS photo contracts. Approximately 34,500 line-miles of high-altitude photography were obtained in areas stretching from northern Ontario to British Columbia by a Lear Jet Model 24. At the same time, conventional aircraft equipped with super-wide-angle-lens cameras were photographing the entire wheat-growing area of the Prairie Provinces, in co-operation with the provincial governments, on the LIFT program.

As a result of these activities, 1970 was a banner year for ICAS photography—492 rolls of black-and-white photography (64,323 negatives) and 30 color rolls (3,500 negatives) were obtained.

GEOLOGICAL SURVEY OF CANADA

The Geological Survey carries out mapping, detection, interpretation, research and advice in the earth sciences and co-ordinates these to provide a national and regional inventory of formations of rocks and surficial materials, their structures, minerals, landforms, and conditions of stability. It develops concepts and techniques to maintain the standard of the inventory and to increase its usefulness and effectiveness.

To meet these objectives the activities of the Branch are carried out by six divisions, one of which is the Institute of Sedimentary and Petroleum Geology in Calgary, and by centralized support services. During the report period the Branch had 473 active scientific projects, of which 174 involved field studies. Most field projects were directed by permanent staff members, although some were led by university professors or postdoctoral fellows. Some studies, especially the federal-provincial aeromagnetic surveys, were carried out under contract.

MINERAL AND ENERGY RESOURCES

Many of the Branch's activities contribute to the goal of estimating the potential abundance and probable distribution of unfound mineral and fuel resources in Canada both regionally and nationally. This includes a complete inventory of the geology of the crustal rocks of Canada leading to an understanding of the sequence of geological events and the processes giving rise to their formation and subsequent alteration, and of the related mineral and fuel deposits that they contain.

This is accomplished by:

a) providing the necessary systematic geological framework to consistent standards as the essential basis for resource estimates; it is derived from various geoscience surveys on land, from the air, from ships, and by employing subsurface information;

b) establishing the geological settings favorable to the occurrence of various types of mineral commodities and fuels resulting from mineral-resource and petroleum-geology studies;

c) identifying such favorable settings within the geological framework and thus delineating potential ground for mineral deposits and for pools and deposits of fuel resources; these are derived from results of geoscience surveys, metallogenic (conceptual) appraisals, and statistical probabilities of the potential abundance and probable distribution of mineral and fuel resources;

d) studies of regional parameters to provide greater consistency of nomenclature and correlation and a deeper understanding of the geological framework than by the systematic surveys;

e) back-up of the above systematic studies by special investigations devoted to: paleontological, radiometric, and paleomagnetic chronology, correlation, and calibration of rock units; the establishment of standards and reference material in respect to analyses, mineral and rock composition, and fossils; specific geological processes and relationships of concern to systematic mapping and resource studies; and pilot projects to test concepts and methods before applying them in a systematic way.

The Geological Survey is close to attaining one of its long-term goals, that of providing the initial complete bedrock geological map-coverage of Canada at a minimum scale of 1:25,000, an effort that will be completed by about 1976. Operation Penny Highlands, carried out in central Baffin Island, the last major unmapped area in Canada, resulted in the mapping of 54,000 square miles of

Precambrian rocks. Two Bell helicopters were used for traversing and an Otter aircraft equipped with oversize wheels was used for support service. All field observations were recorded on forms prepared to facilitate the computer handling of the data.

As part of the national reconnaissance and in response to interest shown by the petroleum industry an aircraft-supported project was carried out to improve our knowledge of the stratigraphy of Prince of Wales Island in the central Arctic. Traversing was by means of a Bell helicopter and a Piper Super Cub equipped with oversized tires, and about 570 landings were made at sites where critical data were required.

A regional geological study of the lower Mackenzie River area was begun in 1968 and completed in 1970. This project combined reconnaissance bedrock mapping, stratigraphic studies and investigation of surficial deposits. In all the area covered was 145,000 square miles, most of which was done in the first two years. Eight preliminary maps portraying the bedrock geology were released during 1970-71. The area examined in 1970 was limited to the Mackenzie Mountains, but the results obtained proved valuable to petroleum exploration being conducted to the northeast.

Several inventory-mapping projects were continued in the Cordilleran Region in order to up-date older reconnaissance studies. Operation Stewart, in the region of the Yukon-District of Mackenzie border was completed, as was Operation Finlay in north-central British Columbia. Similar mapping was commenced in the Snag area of the Yukon, where many parts of the area were explored with the use of rubber boats powered by 33 h.p. motors. The study will be completed in 1971 with helicopters to reach otherwise inaccessible areas.

In the District of Keewatin west of Hudson Bay 1:1,000,000 reconnaissance studies made in the 1950s have been followed in the past few years by more detailed mapping, commonly at a scale of 1:250,000, and by more specialized studies. Last summer a detailed study of the Daly Bay anorthosite complex was begun in order to provide an understanding of the origin, age, and stratigraphic relationships within the body. To the southwest a study of the volcanic stratigraphy and metallogeny of the Kaminak Group of Precambrian rocks was begun. These rocks are similar to volcanic-sedimentary successions in the Superior Province, that part of the Canadian Shield which extends in a horseshoe-shape around Hudson Bay from near Churchill to Ungava Bay. The similarities include the great thicknesses, wide variety and extreme differentiation of the lavas, the presence of iron-formation, the many showings of base metals and precious metals and the complex geological structures. This study strongly suggests that the area, like the analogous parts of the Superior Province, has a high economic mineral potential.

In order to determine the effectiveness of regional geochemical methods, particularly hydrogeochemistry, a study was made in the Kaminak Lake area which, as noted above, has been examined not only on the broad 1:1,000,000 reconnaissance scale but where 1:250,000 mapping has been recently completed. Detailed studies were carried out to examine geochemical dispersion haloes near known metal occurrences. The results, both positive and negative, will be most useful in fulfilling the Survey's responsibility of providing better means of searching for and exploring mineral deposits.

The foregoing provides merely a sample of the Survey's activities that were directed towards the objectives of the Departmental Mineral and Energy Resource Program. Similar inventory mapping activities were carried out from the Strait of Belle Isle, New Brunswick, and Lake Superior to Manitoba and the Interior Plains.

Geophysical and geochemical surveys, a few of which have been noted, were also carried out in widely separated parts of the nation. Most of these activities are undertaken to support the more basic studies and include the development of concepts, criteria, methods, instruments and systems applicable to geology, geochemistry and geophysics and include the federal-provincial national aeromagnetic surveys. This project, started in 1962, was designed to cover those parts of the Canadian Shield not previously surveyed. Since then more than 1.3 million square miles have been mapped, 140,000 being completed in 1970. Maps on a scale of one inch to one mile are the usual method of releasing the data, and these maps now number in the thousands.

EARTH SCIENCES

Under this heading the Geological Survey provides a standard or primary surficial-geomorphology coverage of Canada. As in the Mineral and Energy Resource field this is accomplished by obtaining data, in part for the preparation of 1:250,000 maps. In local, selected areas such coverage is provided in more detail (scale 1:50,000) whereas in remote areas, such as certain regions of the Arctic where information is needed rapidly, preliminary reconnaissance surveys are undertaken in advance of systematic coverage.

The Geological Survey also provides information on the use and hazards of surface and near-surface materials and the dynamics and stability of terrain as it concerns its use by man. Several types of investigations are carried out, including the following:

1) The provision of pertinent information on the surficial geology of specific areas, e.g. the environmental geology of urban areas or the distribution of specific geological materials that have special significance for man's activities on the terrain.

2) Selected investigations concerning the physical and chemical properties of rock and earth materials relating to their use as foundations, sources of usable commodities, tracers, sources of contamination, sources of water, media for transmitting or impounding fluids, and media for disposal of wastes.

3) Studies in selected areas, concerning stability relations of rock and earth materials, sedimentation and erosion, slope stability or movement, and permafrost and ground ice.

4) The study of case histories of geologic-geomorphic aspects of terrain performance or terrain "failures" following land use or resource development.

These studies permit:

5) Prediction and assessment of natural hazards as well as man-induced hazards or pollution.

6) The preparation of land-capability or performance inventories for selected areas.

These investigations are nourished by special studies to provide basic information on terrain processes, mechanics of origin, and on stability and dynamics of various types of terrain, and to devise methods of field and laboratory investigations.

In November 1970, a flume facility enabling a wide variety of sedimentary environments to be studied experimentally was completed for the Geological Survey of Canada. The flume is of the tiltable, recirculating type with a channel 18.3 metres in length. Although primarily suited for studies of stream sedimentation and erosion, it can be readily adapted to the study of certain problems of beach and lake sedimentation and erosion. Controllable discharge, slope depth, and sediment characteristics provide a high degree of flexibility in the application of the flume to numerous environmental problems involving erosion and deposition.

During the 1970 field season inventory mapping of surficial deposits was carried out in many parts of Canada. In the Arctic a study of the glacial geology and geomorphology of southern Ellesmere Island and Devon Island was continued, and similar studies were undertaken on Herschel Island, Yukon, and on the Mackenzie Delta and Arctic Coastal Plain. Studies in the latter areas will be considerably increased in 1971 in support of a study of the Mackenzie Valley Transportation Corridor. Similar studies were made in more settled parts of Canada, including southern Labrador, southwest Cape Breton Island, Kingston and Arnprior areas of Ontario, Winnipeg map-area and the Assiniboine River valley of Manitoba, the South Saskatchewan River area, and in several map-areas in southern and central British Columbia.

In conjunction with studies directed toward the search for mineral deposits a project designed to sample surficial materials was carried out in the Kaminak Lake area of the District of Keewatin. Samples of glacial till, marine sediments and esker sediments were collected on a predetermined grid pattern for analysis to determine the dispersal patterns caused by glacier transport of mineral and rock fragments and trace elements from their source areas. Sample sites were reached by helicopter and at each site a pit 20 to 30 inches deep was dug from which the samples were selected. As many as 45 were collected each day.

The increasing expansion of Canadian cities has focussed attention on the need for land-use planning as a basis for orderly and efficient development of urban-centred regions. Geoscience data are significant components of the information needed by planners, developers and administrators concerned with multiple land use. Such studies could be classed as "environmental geology" and include management of land resources, water resources and subsurface fluids, waste disposal and usable rock and mineral materials (E.G. sand and gravel). In view of the increasing need for this type of information the Geological Survey undertook a prototype study of a 3,000-square-mile area to develop methods of compiling, evaluating and presenting the required data. During the 1970 field season data from 3,100 boreholes were compiled from existing sources and were coded in a form suitable for a computer program, from which it is expected that maps displaying the data can be produced. Surficial mapping at a scale of 1:50,000 was carried out in parts of the area. The engineering-geological characteristics of bedrock material were examined in order to assess the influence of bedrock topography on future land use, the effects of bedrock characteristics on foundations, the excavation characteristics of various rock types.

DEVELOPMENTAL ACTIVITIES

In support of its main objectives in the fields of mineral and energy resources and earth sciences, the Geological Survey seeks to improve the methods whereby data are acquired, to develop new concepts and instrumentation, and to establish physical, chemical and paleontological standards.

In geophysics, development continued on airborne gamma spectrometry, and two experimental area surveys were undertaken. The results of this work, reported in *GSC Paper 71-1, Part A,* showed that the technique is successful, and they also disclosed several prominent radiometric anomalies similar to those that are associated with known uranium areas such as Elliot Lake, Bancroft, Uranium City or Wollaston Lake. It appears that these new areas have a better-than-average potential for radioactive mineral deposits.

Seismic-survey techniques were also used in support of many projects in order to obtain strata thicknesses. Such studies were carried out in eastern Ontario, along the Toronto waterfront, along the route of the new Welland Canal channel, and in the Beaufort Sea north of the mouth of the Mackenzie River, where both reflection and refraction techniques were tested in an attempt to define the base of the permafrost.

The Geological Survey continued to be in the forefront of the development of geochemical exploration methods, and a major achievement was the successful application of these techniques in areas of permafrost by using surficial materials as the sample media. A field project in the Coppermine area demonstrated that these techniques have a real potential as an exploration tool, and the data collected lend themselves to presentation by computer-produced maps.

Standards of time and stratigraphic sequence are necessary for proper correlation of geological events. Dating of rocks is achieved by physical and paleontological methods. During the report period 182 K/Ar age determinations were made, as were smaller numbers of Rb/Sr and U/Th/Pb age determinations. A new 15-inch solid-source mass spectrometer, completed and tested during the year, will be used mainly for high-accuracy lead and uranium isotopic analysis. Radiocarbon dating is used for organically-derived materials dated in thousands rather than millions of years. A total of 224 determinations were made, mostly to support Survey studies, but some for the National Museum of Man to date archeological sites. Many thousand of fossils were identified, both from collections made in the field and from well-core samples. All these "dating services" greatly facilitated the studies carried out by the Survey.

GENERAL

In order to make the results of its studies available to government, industry and the general public, the Branch, supported by Public Relations and Information Services, has an extensive publication program. During the year 1 memoir, 7 bulletins, 3 economic geology reports, and 60 preliminary papers were published, and 30 manuscripts were made available to the public by means of Open File reports. The most significant item published during 1970-71 was the 5th edition of the book *Geology and Economic Minerals of Canada,* an 838-page text accompanied by a folio of 8 multicolored maps and correlation charts illustrating all aspects of Canadian geology. In addition, 354 new aeromagnetic maps were released and, in order to keep older information readily available, 24 publications were reprinted, as were 205 aeromagnetic maps. In addition to these publications members of the staff published 166 papers in outside journals, gave 108 presentations to scientific meetings and delivered 85 university lectures.

To stimulate research in the solid-earth sciences at Canadian universities the Geological Survey, on the advice of the National Advisory Committee on Research in the Geological Sciences, awarded $228,000 in general grants-in-aid during the report period.

Earth science is demonstrably valuable to Canada's national wellbeing. Since much non-renewable resource information is gained by commercial corporations based and controlled outside of the country in competitive situations requiring security of information, it is essential that the Government of Canada be provided with its own cadre of experts in order that our resources be effectively managed. This the Geological Survey endeavors to do. The results of the year 1970-71 amply illustrate how this requirement was met.

MINES BRANCH

PHYSICAL METALLURGY

During the period of this report, the Physical Metallurgy Division conducted research and development work in support of the Mines Branch activities on minerals and metals technology, and environmental improvement. The major portion of this work is related to the conservation, processing, properties, and utilization of Canada's metals, and the fabrication of products from these metals. The Division also undertakes work for the Departments of National Defence, Public Works, and Transport.

Research activities are based on an assessment of present and future requirements for continued technological growth. Emphasis is on applied research and development that needs pilot-plant-scale melting, casting, and fabricating facilities, to provide the maximum assistance possible to the Canadian economy in general, and to the metallurgical and resource industries in particular.

The applied research of the Physical Metallurgy Division covers three activities of the Mines Branch. These are: pollution abatement, processing of metals and alloys, and the evaluation and improvement of metals and alloys. The Division also carried out a number of special investigations for other government departments.

Pollution Abatement

The problem of air pollution by the Canadian iron and steel industry is of vital importance. A report entitled *A Canadian View of Steelmaking Air Pollution* has been prepared to serve as a basis for evaluation of the feasibility and suitability of studies of pollution abatement in the iron and steel industry that might be initiated within the Division.

Processing of Metals and Alloys

The purpose of this activity is to further technological development in converting Canada's mineral resources into useful metal products, in order to meet the changing needs of industry and the Canadian economy. Processing operations such as melting, casting, forging, rolling, welding, and powder metallurgy are studied under this head.

The Leigh Oxygen Probe System, which was developed in these laboratories, is being used to study soluble oxygen contents in basic electric steel, to relate the soluble oxygen content of rimming steel to ingot structure, and to study the deoxidation reactions under conditions similar to those existing in commercial steel plants.

Research is being carried out in specific areas of foundry technology dealing with the flow of metals in moulds, moulding materials and specialized moulding and casting techniques.

X-ray television fluoroscopy is being used to study the manner in which molten metal enters a mould cavity. These studies have shown that complete filling of a sprue does not occur unless the dimensions are somewhat less than those predicted by present theories.

Studies on melting and solidification deal with phenomena occurring in the melt and in the solidification of metals, which influence the quality and characteristics of the solid product.

The form and distribution of graphite in cast irons have a major influence on their properties. Work on the malleableizing process for white cast iron has indicated that the nuclei of the graphite particles are formed during solidification, rather than on subsequent heating. Graphite formation in thick-section nodular cast iron is adversely affected by small amounts of lead, antimony and bismuth. An investigation of this problem is in progress.

The characteristics of the particles of metal powders vary with the process by which the powders are made. The type of powder also influences the processing and quality of the powder-metallurgical product. Nickel and iron powders from various Canadian manufacturers are being studied to determine the particle characteristics and their influence on production processes.

Research is in progress to study the heat-affected zone-cracking tendencies of welds in structural steels. The validity of using fillet-welded assemblies to evaluate heat-affected zone cracking in butt-welded joints is being examined. The notch ductility of the welded joints produced in a shipyard by five different welding processes, using CSA G40.8 Grade B steel, is being examined in order to provide data useful to the Canadian Armed Forces in selecting welding processes for shipbuilding. It has been shown that the properties of the welds differ significantly with the welding process used.

Research is being conducted, in co-operation with the galvanizing research sub-committee of the Canadian Lead-Zinc Research Committee, to study the reaction kinetics of the iron-zinc system, in order to obtain basic information on the rate laws governing the reaction and to indicate methods by which galvanized-coating formation and properties can be improved and controlled. A group of steels containing silicon is being examined over a range of galvanizing temperatures and steel pretreatment conditions. Silicon-containing steels are normally difficult to galvanize.

Evaluation and Improvement of Metals and Alloys

The work in this field is concerned with understanding relationships between properties and composition so that the usefulness of metals and alloys can be established. This work is designed to meet the future potential needs of the Canadian economy and defence needs for new and improved alloys suitable for use in our environment, and adapted to the most effective utilization of our mineral resources.

A study is being conducted of the relationship between the mechanics of brittle fracture and ductile fracture in high-strength alloys. An extensive fractographic investigation of the environmental cracking of 18% Ni maraging steel in 3.5% NaCl solution has been completed. Significant variations in fractographic appearance have been observed which can be correlated with stress-corrosion or hydrogen-embrittlement cracking.

Knowledge of the dynamic fracture toughness of structural steels and the effect of thickness on this property is important in a number of applications, especially in the Arctic. Research to date has concentrated on the development and refinement of experimental techniques required in this research.

The effect of variations in rolling conditions on the strength, toughness and microstructure of G40.8 Grade B steel has been determined. The effect of rolling temperature and pass reductions on the loads imposed on the rolling mill is also being studied.

The influence of aluminum, nitrogen, sulphur and silicon within normal composition ranges upon the susceptibility to hot and cold cracking of welds made in a carbon-manganese structural steel is being investigated. Work to date has indicated that there is a critical range of aluminum content for which hot ductility about 1090°C (2000 °F) is considerably reduced, thereby increasing the susceptibility to hot cracking on welding.

A joint project is being carried out in co-operation with Endako Mines Ltd., Vancouver, B.C., to develop a new chromium-nickel-molybdenum stainless steel. Three of the experimental alloys produced are being field-tested as fine wire mesh in a papermaking environment.

Research on stainless maraging steels has demonstrated that beryllium can be substituted for titanium as the age-hardening constituent, and that the optimum chromium and nickel content in this class of alloy would appear to be 12% Cr and 8% Ni.

Titanium alloys are attractive as structural materials because of their low densities and high potential strengths; the strongest of them, however, suffer from low ductility. Alloys suitable for structural purposes are being evaluated to determine both their susceptibility to environmental cracking and weldability. The problem of low ductility of high-strength alloys containing more than 13 at .% Al is being investigated, and hardening mechanisms in a high-strength Ti- 45% V- 2% Si alloy are being studied.

A detailed study of the aging mechanisms in the commercial magnesium alloys Mg-9Al-Zn and Mg-Nd-Ag-Zr is being made to help determine the optimum properties for these alloys.

Special Projects

The following items are typical examples of investigations that have been undertaken during the past year in response to specific requests.

As a result of their investigations, scientists of this Division were able to reconstruct the sequence of events that led up to the major explosion on HMCS *Kootenay,* and were therefore able to identify the cause of this disaster.

The Physical Metallurgy Division acts as examining authority for the certification of personnel for nondestructive testing on behalf of the Canadian Government Specification Board (CGSB). Since the initiation of the program ten years ago, 1,797 radiographic and ultrasonic test personnel have been examined, and about 86 per cent of these were certified.

In the Defence Research Board research vessel *Quest* the inside surface of the steel fuel ballast tanks is partly lined with acoustic tile having a high graphite content. The

remaining steel surfaces are coated with an inorganic zinc paint. The tanks usually contain a seawater layer beneath an upper fuel layer. It was requested that the likelihood of corrosion be investigated. Laboratory tests indicated that such corrosion was not likely.

Reports, Investigation and Requests for Information

The Division issued 177 reports during the period under review. This includes reports and publications on research, reports on technical visits and committee work, and reports on investigations.

In addition to these services, the Division also dealt with 245 requests for information and advice that could usually be answered by letter; 117 such inquiries came from 87 Canadian companies and 128 originated with 25 government agencies.

FUELS RESEARCH

The decline in the rates of production of natural gas and petroleum in the United States in the face of growing demand is a matter of growing concern, and has made governments around the world more conscious of the role played by energy in sustaining a reasonable standard of living. Canada is no exception, and the Fuels Research Centre, which is the agency of the federal government responsible for evaluating the quality of the fossil fuel resources and for developing new engineering and scientific approaches to encourage their efficient utilization, has had to accelerate its resource-evaluation work.

To concentrate the activities of the Fuels Research Centre on major national needs in a manner that would permit better financial support and control under the Department's Mineral and Energy Resources Program, the research work is conducted under two heads: (1) energy and (2) environmental improvement.

The relocation and reconstruction of facilities of the Fuels Research Centre at the new site near Bells Corners, Ontario, 12 miles from Ottawa was completed with the construction of the diesel-engine testing facility of the Canadian Explosive Atmospheres Laboratory. This relocation of the Centre, though expensive and time-consuming, has led to improved operations.

Under the energy program, plans were made by the Department in the spring of 1971 to support a joint drilling program with the Province of Saskatchewan to determine the amount of lignite available for potential use as a source of thermal power. It was recognized that it was not known to what extent it was possible to differentiate leonardite from lignite by conventional geophysical methods. As the calorific values of these two minerals differ widely, a program was initiated to drill and core some exploratory holes in areas where these minerals were known to occur. The analysis of these cores and the associated log data will provide a basis for planning the large-scale drilling program which was to begin May 1, 1972.

Measures to improve the quality of the environment may be divided into projects concerned with (1) the improvement of combustion processes and the elimination of pollutants after combustion by dispersion into the atmosphere; and (2) the elimination of sulphur from the fuel and the improvement of fuel quality before combustion.

As a result of aerial surveys of Boundary Dam, Saskatchewan, and at McMurray, Alberta, significant progress was made in the development of improved techniques for aerial probing of hot smoke plumes from tall chimneys. This had led to a better understanding of the dispersion phenomenon and the capacity of air sheds to absorb pollutants. A consequence of this work will be a much-improved basis for the design of chimneys to protect ambient air quality and to give an indication of the levels of industrialization that are possible with existing technology.

The efforts made to develop a satisfactory thermal method for the destruction of liquid DDT has culminated in the construction of a $150,000 incinerator by the Defence Research Board at Suffield, Alberta, based on the design developed in the Canadian Combustion Research Laboratory. Further research has led to the development of equipment for the thermal destruction of DDT in powder form. Technical bulletins describing the research on both liquid and powder DDT have been published.

The growing need for information on the incineration of municipal waste has been met by publishing a bulletin describing a variety of commercially available equipment, including many of the technical factors that must be considered in the selection of the most suitable equipment.

An efficient route to thermo-electric power from fossil fuels without air pollution, requiring a minimum of coal preparation and capital investment and yet possessing excellent turn-down capability, is through gasification followed by combustion and subsequent conversion of the

heat to electric power through steam and gas turbines. Calculations are in progress to find the areas in Canada where such advanced technology might be applied.

It is inefficient to attempt to desulphurize the combustion gases arising from domestic heating and automotive and diesel transport. The sulphur must be eliminated prior to combustion. As the high-grade low-sulphur crude oils are gradually being consumed, it becomes increasingly important to devise inexpensive ways of refining low-grade high-sulphur crude oils. During the year the Mines Branch studied intensively thermal hydrogenation and catalytic hydrogenation in the liquid phase to determine the savings that could be achieved as compared with the conventional coking process. It has been shown that substantial savings through increased liquid yields can be realized.

To provide a more convenient reference for Canadian pollution studies, a listing of the sulphur content of Canadian crude oils in ascending order has been prepared. This listing makes the data in the Canadian oil-analysis directory more accessible and easier to use for this purpose.

The development of more powerful analytical tools plays an important role in petroleum research, and the benefits are felt in a wide variety of problems, from evaluating the quality of the crude oil resources to the identification of marine oil spills. In this connection new chromatographic columns employing lithium chloride supported on diatomaceous earth were found to separate the sulphur-containing compounds with high resolution at relatively low temperatures. The performance of these columns has been carefully studied by measuring the retention times of pure organic compounds containing a variety of sulphur linkages. This work gives every indication of living up to its promise of providing an excellent means of fingerprinting petroleum. The interest shown in this research and the financial support given to this program by the Department of the Environment are gratefully acknowledged.

A concern of the western Canadian coking-coal industry is the loss of coking properties that occurs through oxidation. This could occur through the oxidizing action of ground water on coal and exposure to air during mining, processing, transportation and storage. The study of this oxidation process is undertaken in order to design chemical methods of preventing or slowing down oxidation. The indications from the work of the past year are that coals differ considerably in their oxidation behavior but that in certain coals functional groups are formed which undergo condensation reactions on heating. The bonds formed as the result of this reaction prevent the coal from melting and forming strong coke.

Progress was made during the year on the development of a method for examining the maceral composition of fine coal. This advance promises to be very useful in studying coal when ground to the fine sizes required in pipelines, and for pyrite removal by electrostatic methods.

The Canadian Explosive Atmospheres Laboratory, the agency responsible for the certification of electrical equipment in mines where combustible gas mixtures may exist, expanded its facilities during the year through the construction of the diesel investigation facility. This specialized laboratory was established to improve the measurement of the exhaust emissions from diesel-powered mining equipment and safety with regard to explosion hazards. The official end of the construction stage of the laboratory was November of 1971, and it was expected that the remaining instrumentation would be completed early in 1972.

Research by the laboratory during the year covered the physical effects on the enclosure walls by short pulses of high pressure, and the correlation between plasma density and propensity to arc between electrodes. The increasing demands placed upon the certification service by industry have made it difficult to keep the research abreast of the need for basic information that is required to make certification judgments.

MINING RESEARCH

The Mining Research Centre has staff and facilities located at Ottawa, Elliot Lake and Calgary. More staff is now located outside Ottawa, at the Elliot Lake Laboratory and the Western Office, than in Ottawa at the Canadian Explosives Research Laboratory and the Rock Mechanics Laboratory. However, the actual work, which is done substantially in co-operation with mining companies, is spread throughout the country. The Western Office will make it easier to work with the western coal, base-metals and potash mines.

The Centre operates on the project system, many individual projects being integrated with the work of individual companies and universities. Wherever possible the prospect of an attractive payoff is used in the selection of projects. Those projects on which the potential benefit-cost ratio is particularly high receive maximum concentration of the budgetary resources.

Rock Breakage

The breaking of rock both at the mining face and subsequently in reducing the large blocks of ore to a fine size suitable for processing is a major part of mining. One objective is to explore the mechanics of breakage using forms of energy other than explosives that may lead to radically new mining methods. This is a pioneering activity undertaken at the request of the Mining Association of Canada as a result of a survey showing that its members believe rock breakage is one of the most important areas in which research should be able to effect savings.

Beside helping to increase efficiencies in current systems through the discovery of novel methods of drilling, blasting, crushing and grinding, it was also envisaged that conventional operations might be telescoped into some combined procedure quite unlike current practices. Simulation techniques using computers for the analysis and control of grinding circuits are also being developed. An investigation has been undertaken of the economic and technical feasibility of using modified wedging tools to remove rock as part of a tunnelling machine.

Blasting research is also being pursued to increase safety and to reduce the cost of drilling and blasting in industry, which accounts for the expenditure of approximately $130,000,000 per year in Canada. By the application of analytical techniques it should be possible to produce significant savings within a reasonable period of time. The resources of the Canadian Explosives Research Laboratory, the Rock Mechanics Laboratory and the Elliot Lake Laboratory, together with those of some private companies, are all being used for this work.

Ground Control

Canadian underground and open-pit mines will become deeper. The ground-control problems encountered at depth will be more severe than those presently existing. The present basis of engineering experience and trial-and-error procedures may not be sufficient to deal effectively with these problems. Consequently, a basis is required to aid judgment on what should be done once problems occur. The science of rock mechanics is not at the stage where mining excavations can be designed completely, and due to the complex nature of ground conditions rigid predetermined planning may not be feasible. At present, research provides relevant information to mine operators that assists them in making decisions regarding mining layouts, extraction, and artificial support systems.

With the increase of rock-mechanics activity in Canada the role of government mining research has changed. It is now developing comprehensive theories on rock deformation and failure; evaluating instrumentation suitable for Canadian mines; and dealing with projects which demand a multi-disciplined approach. At present these functions are beyond the scope of most mining companies. In addition, the engineers working at one mine are familiar mainly with conditions at their own mine, whereas government research scientists who visit and conduct projects at mines through Canada build up a broad backlog of experience. This experience is useful in providing advice on request to mining companies when ground-control problems occur.

Ground-control research is divided into basic and applied projects, and an even balance is sought between the two. Basic projects are oriented towards the simulation of geological and excavation conditions; providing basic information of mine rock; and evaluating rock-mechanics instrumentation. Applied projects are oriented towards solving typical problems in mines and deal with: roof stability in salt and coal strata; wall and pillar stability in hard-rock mines; the stability and the use of artificial support for open-pit slopes; and the problems of outbursts in coal mines.

Research is being carried out at three laboratories: the Rock Mechanics Laboratory, Ottawa, where mainly theoretical work is carried out; the Elliot Lake Laboratory, where applied research is done in the hard-rock and evaporite mines; and the new Western Office in Calgary, which is presently concerned with the problems in coal mines.

Environmental Control

Respirable dust has long been recognized as the cause of a pulmonary occupational disease called pneumoconiosis. In Canada modern mining methods have increased the amount of respirable dust produced in mines. Improved ventilation has countered the serious damage that would have occurred. Co-ordinated efforts of governments, universities and industry are required if the quality of the mine environment is to be improved and the respirable-dust problem eradicated.

The work in this area has been directed towards certain neglected areas of the physics of dust measurements, such as (1) the development of standard methods of measuring dust and radiation hazards; (2) the classification of mine environments in terms of dust hazards based on rock-dust relationships; and (3) more efficient ventilation.

The need for and the benefits derived from this program have been corroborated by industry. At the present time, research on the standardization of methods for measuring dust and radiation hazards are being conducted in close co-operation with the Mine Accident Prevention Associations of Ontario and Quebec as well as with individual companies experiencing critical problems. The payoff for this program will be realized if the increased knowledge results in reduced compensation payments and in safety codes that will safeguard the health of the miner with the minimum impedance to technological advances in production.

The work is being done primarily at Elliot Lake.

Mine Systems Engineering

Work has been started on systems analyses of various mining operations. Advances that are made by physical research on the various phases of operations (drilling and blasting, ground control, transportation, etc.) are being examined to determine their influences on mine economics. Computer programs are being developed for use by company staffs on mining properties.

With the high degree of complexity of current technology, we find that no organizations exist in the country with the personnel and facilities capable of assisting those with problems in many specialized areas. Consequently, calibration, testing and advisory services are provided when required by companies and agencies in the mineral and associated industries. This is consistent with the Mines Branch policy of orienting its research to fill gaps in technology of particular concern to the country. At present, most of the work is being performed at the Canadian Explosives Research Laboratory.

The general function of communication is being expanded by the development of an Information Centre involving both the Mines Branch Library and the Elliot Lake Laboratory. Through information officers and telex links it is planned to provide industry and the universities with assistance in obtaining the latest research information on any subject. At present, integration with private research is achieved either through joint projects or through liaison on subjects of mutual concern. The companies co-operating with the Mines Branch in research produce approximately 75 per cent of the Canadian mining output. Besides the conventional method of publishing significant results in journals, interim reports are written. Some of these are distributed exclusively through the Mining Association of Canada to interested companies, while others are used as research notes that are exchanged with laboratories both in Canada and abroad.

Canadian Advisory Committee on Rock Mechanics

In 1963, the Canadian Advisory Committee on Rock Mechanics was formed to stimulate greater interest in this base science for mining and to co-ordinate research. The membership has consisted primarily of representatives of industry and of the universities, with Mines Branch personnel providing the secretariat.

During the past year, one of the committee's specialist panels completed a study of the requirements for rock foundations. It is expected that new Canadian building standards will result from this study.

One of the principal ways in which the Mines Branch, with advice from the committee, has been able to stimulate research is through its grants-in-aid which, starting with $10,000 in 1962, have grown to a total of $363,000 for mining research. The committee also periodically examines and appraises the research of the centre in rock mechanics.

MINERAL SCIENCES

There has been a significant change in the direction of effort in the Mineral Sciences Division during the fiscal year 1970-71, and particularly during the latter part of that year. In order to bring the work of the Division more into line with current departmental objectives, materials research has been considerably curtailed and has been replaced by work in the environmental improvement field insofar as this relates to the mining and metallurgical industries, largely making use of equipment and expertise available in the Division. There has also been a significant expansion of the Division's effort in the field of standards of various types. Some of the more notable developments in the various programs are detailed below.

Sulphides

In the characterization of sulphide minerals, on which much of Canada's base-metal industry depends, studies of the crystallography of various types of pyrrhotite, chalcopyrite, cubanite and related minerals have been conducted. Subtle variations of composition and structure are thought to have a bearing on the ease or difficulty encountered in beneficiating ores containing these minerals. Several hitherto unknown variants have been isolated and characterized compositionally and crystallographically.

The work on the growth of synthetic sulphides and related compounds intended to simulate naturally occurring mineral species and to be used for various crystallographic and physical studies has been continued throughout the year, with a range of techniques.

Regional studies of mineralogically significant areas in Canada have been continued. The extensive studies of the silver deposits in the Cobalt-Gowganda area of northern Ontario, conducted over many years, have been brought to a successful culmination with a comprehensive and definitive publication of the findings. Studies are currently under way into the mineralogy of the porphyry copper-molybdenum deposits in the Highland Valley area of British Columbia, the base-metal deposits in the Red Lake area of northwestern Ontario, and the tungsten-tin deposits in southwestern New Brunswick.

Materials Research

As mentioned above, certain work in this field has been curtailed during the latter portion of the fiscal year 1970-71. This includes the series of high-temperature phase-equilibrium studies in multi-oxide systems conducted over many years, also the work on magnetic ceramic materials (ferrites). Both projects are being gradually terminated with the publication of the results. In the phase-equilibrium work, the systems $CaO\text{-}Nb_2O_5\text{-}TiO_2\text{-}SiO_2$, $ZnO\text{-}Nb_2O_5\text{-}SiO_2$ and $CaO\text{-}Fe_2O_3\text{-}Al_2O_3\text{-}SiO_2$ have been studied and significant advances made in our knowledge of these systems which have mineralogical and/or technological significance.

Studies of "hard" or permanent-magnet-type ferrites have been concluded with the publication of a series of papers dealing with the ceramic and magnetic properties of strontium, barium and lead hexaferrites. The study of "soft" or spinel-type ferrites, widely used in computer and magnetic-tape applications, have been continued with statistically-designed experiments. In the fabrication of these materials, the application of the freeze-drying technique has been found to be particularly applicable.

Analytical Research and Services

This program has led, during the past year, to several developments that are significant to the mining/metallurgical industries. Foremost among these is the increased involvement of the Division in the development of various types of standards—namely, standard methods of analysis and standard reference materials.

A project is under way to develop a group of standard reference ores of various types that are typical of mineral deposits in Canada. A co-operative analytical scheme, involving many outside as well as governmental laboratories, has been applied to these ores and the results assessed statistically. The ores can now be certified for several elements to within specified limits of accuracy, thus providing reference materials that can be used to monitor analytical procedures for these elements. The materials to which these procedures have been applied include platinum-bearing samples, such as a British Columbia alluvial sand, and a Sudbury copper-nickel matte; the work is being extended to include a Sudbury concentrate. A molybdenum ore from the province of Quebec, a complex W-Sn-Zn-Cu ore from New Brunswick and a Cu-Mo ore from British Columbia are also being investigated for similar purposes.

The Division continues to be heavily committed to the development of nationally and internationally acceptable standard methods of analysis for metallic constituents, on behalf of the Canadian Standards Association, the American Society for Testing and Materials and the International Organization for Standardization (ISO). Metallic standards for emission-spectrographic work are also under development. In all these aspects of standards work, the use of statistical procedures for evaluation of the results is increasing; such methods are also being used in assessing the techniques of sampling and of processing the ores.

The use of on-stream analysis of slurries is becoming increasingly significant in mineral beneficiation and processing. The Division is conducting studies involving the use of X-ray fluorescence in such work; in some instances the X-radiation is excited by employing radio-isotopes such as Cd-109. The technique of nuclear magnetic resonance spectroscopy is being adapted to estimate the water content of the slurry, thus providing a complementary means of analysis.

Environmental Improvement

As part of the Mines Branch program on this topic, the Division has recently undertaken a group of projects designed to improve the environmental aspects of mining and metallurgical operations. These include:

(i) A study of the various factors that affect the composition, in regard to pollutant elements, of the effluent waters from slag heaps, tailings piles and tailings ponds.

(ii) A study of open-layer silicate minerals (e.g. bentonite) that could be used as possible ion-exchange media for removing the pollutant elements from such effluents.

(iii) A phase-equilibrium study of the systems (Fe,Co,-Ni)-S-Cl, to provide information designed to be of use in devising alternate means of treating sulphide ores, thus eliminating the need for oxidative roasting, by attacking the ores with moist hydrochloric acid gas at elevated temperatures.

(iv) A comprehensive study of the methods available for the reduction of the SO_2-emission in stack gases from sulphur-bearing coal combustion or from sulphide-ore roasting operations.

EXTRACTION METALLURGY

In the Extraction Metallurgy Division, research and development were continued on hydrometallurgical processes, pollution abatement, and control of metal corrosion. Studies were also made of the kinetics and thermodynamics of various metallurgical reactions of importance in these fields. The results of the research were made available to the Canadian mining and metallurgical industry in Mines Branch reports and published papers, and through joint organizations such as the Canadian Mineral Processors, Canadian Mineral Analysts and the Canadian Uranium Producers' Metallurgical Committee, as well as through informal direct contacts.

Metals Extraction and Recovery

Over the past two years the leaching of uranium from coarse ore has been studied with the objective of developing a system of static leaching in mine stopes or in heaps above ground, utilizing bacterial action, to minimize mining and leach-plant costs. Pilot-plant tests on minus-8-inch Elliot Lake ore have indicated that an extraction of 85 per cent of the uranium may be obtained over a period of two years. More recently a co-operative study was carried out jointly by a Canadian uranium-mining company and the Mines Branch under actual mine conditions, and parallel results were obtained over a 30-week period. This investigation was terminated by suspension of mining operations, but it is clear that underground leaching of coarse uranium ore is a practical and effective way to treat some Canadian uranium ores.

One of the problems in using bacterial action to extract uranium from ores is that the resulting solutions contain much iron. A study was made on ion exchange as a method to recover uranium from such solutions. A weak-base anion-exchange resin with a very much higher selectivity for uranium than for ferric iron was found quite suitable for recovering uranium from liquor containing up to 10 g/l ferric iron. This technique overcomes the problems that have heretofore made the utilization of bacterial action for uranium extraction unattractive.

Solvent extraction can also be used to separate uranium from iron-containing solutions, and in this case the possibility exists of making the separation from a leach pulp, thus eliminating the filtering operation and reducing the treatment costs. The use of a sieve-plate pulsed column was investigated for this purpose, and it has been shown that 99 per cent of the uranium can be extracted with a loss of organic extractant of 0.13 lb/ton of dry feed. While this is an acceptable loss, work is under way to reduce it.

Solvent extraction has also been applied to the conventional ammoniacal pressurized leaching process for copper-nickel-cobalt ores. Here the conventional separation of nickel and cobalt is a rather complex operation. Using solvent extraction, clean separation of copper, nickel and cobalt can be achieved in rather simple ways. This work has been confirmed by two companies using their own solutions.

Environmental Improvement

Because of the problems of disposing of the sulphur dioxide generated in the conventional smelting processes for treating sulphide ores, a continuing search is being made for alternative hydrometallurgical routes that will be acceptable economically. For mixed sulphide concentrates of copper-nickel-cobalt, a pressurized leaching process, using either air or oxygen as the oxidant, is attractive, since this process is capable of converting much of the sulphur to the elemental form, which is non-polluting. Major problems to be overcome in utilizing this approach are the slow dissolution of copper that occurs when the copper mineral to be dissolved is chalcopyrite, and the extraction of dissolved copper from the iron-oxide residue. Work during the past year has shown that both these problems can be overcome, and there is now every reason to believe that this process can be made a commercial reality.

One of the minerals of perennial interest to Canadian metallurgists is the iron-sulphide pyrrhotite, because it is

of widespread occurrence and often associated with the valuable metals copper, nickel and cobalt, and because it contributes much of the sulphur dioxide generated in smelting processes. One process examined for treating it hydrometallurgically is hydrochloric-acid leaching. In this case the sulphur can be recovered in elemental form, the valuable metals can be isolated as high-grade concentrates, while the iron appears as a concentrated iron chloride, from which the hydrochloric acid can be regenerated.

Attractive as this process appears on paper, recovery of the hydrochloric acid is probably too expensive to make the process as a whole commercially attractive. However, a recent observation has suggested that if sulphuric acid is substituted for hydrochloric acid, the acid-recovery step can be simplified while retaining the attractive features of the hydrochloric acid approach.

While control of sulphur-dioxide emissions from plants treating sulphide ores and concentrates is certainly technically feasible in principle, a more difficult problem is presented by sulphur-dioxide emissions from the burning of coal and oil, partly because the gases are more dilute. While limestone has been extensively investigated as an agent for trapping sulphur dioxide, it has never been made efficient, and it also presents a solid-waste-disposal problem. Our work has shown that magnesium oxide supported with an iron-oxide catalyst can quantitatively absorb sulphur dioxide from dilute gas streams, and that the sulphur dioxide thus absorbed can be regenerated either as a concentrated gas for converting to sulphuric acid, or for reduction to elemental sulphur with coal, for example. As a result of the regeneration of the sulphur dioxide the magnesium oxide is also regenerated for reuse, thus eliminating the solids-disposal problem.

Although many metallurgical operations are free of problems associated with sulphur-dioxide production, all such operations cause water pollution. Many of these problems have been adequately dealt with over the years, but new and more stringent regulations are presenting operators with new challenges, as for example, controlling the emission of salts of copper, zinc and iron in liquids discharged from certain milling operations. The problem is complicated by the fact that the solutions are very dilute. However, it has now been shown that ion-exchange resins of the sulphonic-acid type can treat solutions of the kinds found in the Noranda and Sudbury mining areas, to yield final effluents that can be safely discharged into existing water courses.

Corrosion Prevention

Corrosion continues to be a significant cost factor in the mining and metallurgical industry. A survey of Canadian base-metal mines recently published by our staff showed that underground machinery and mill processing equipment commonly had inadequate protection. A number of test programs were initiated to try to reduce the effects of sulphur-dioxide gases and of acidic salts generated by the oxidation of sulphide-bearing dusts. New apparatus for simulating mill and plant atmospheres has been developed which makes it possible to accelerate testing of newly developed coatings to resist wet sulphur dioxide.

The formula of a conventional chemical conversion coating was successfully modified to include a novel accelerator, hexamine, and manganous acetate instead of manganous sulphate, to produce a coating impervious to a water-saturated sulphur dioxide. Studies were also made on conventional oxalate and phosphate conversion coatings to improve their resistance to mine and mill atmospheres. In addition, experiments were conducted in a grinding circuit to see if an economical corrosion-control method could be found to reduce ball and liner consumption. Results so far indicate that 20 per cent of ball and liner consumption is caused by corrosion.

The program on electroplating was continued in an attempt to find more effective and cheaper coatings for protection against salty atmospheres. A start was made on the development of non-porous electroplated coatings by studying the performance of thin chromium platings from our low-ratio plating baths containing sodium hydroxide. Increasing the sodium hydroxide content of the plating bath improved corrosion-protection capability of thin coatings by reducing the number of cracks and pits per unit area that occur in conventional platings.

Chemical Analysis

A large number of samples was analyzed for a wide variety of constituents in support of the Division's research. Advanced concepts in ore hydrometallurgy and enforcement of stricter pollution controls necessitated analytical research to modify existing procedures and to develop new procedures.

An investigation was made toward improving the procedures used in the atomic-absorption and flame-emission method for determining mercury in caustic cell sludges. One of the changes resulting from this study was the elimination of the oven-drying step in the conventional

analytical procedure, which was found to give erroneous results.

More accurate measurements on xanthates and dithiophosphates in flotation liquors of operating mills are required to control reagent consumption more effectively and to improve grade and recovery of sulphide concentrates. To meet these demands, work began on the application of the silver-sulphide membrane electrode for the continuous on-stream control of reagents employed in flotation processes. The experimental work to date has shown that both xanthates and dithiophosphates can be determined in the presence of other constituents in flotation liquors.

Arsine, evolved in the process to recover gold from arsenic-bearing cyanide solutions, is an extremely toxic gas which has caused some near-fatalities in two operating gold mills in Canada. In view of this situation, the problem of arsine evolution and the development of methods to prevent its formation were investigated. A substantial reduction in the amount of arsine formed can be achieved by either oxidizing the arsenic present in solution to arsenate with potassium permanganate, or by adding copper salts to render the metallic zinc inactive to the dissolved arsenic. Studies on the problem are continuing.

In anticipation of increased trade in uranium and its products between Canada and the United States in the near future, the analytical laboratories of this Division have been approved by the U.S. Atomic Energy Commission as an official umpire to represent Canadian interests.

METALS REDUCTION AND ENERGY

The Metals Reduction and Energy Centre completed its first full year of operation in fiscal 1970-71. The Centre was established to link research in pyrometallurgy with many of the activities in the metallurgical-coal and carbonization industries of Canada. Laboratories working at the pilot-plant scale are at two locations in the Ottawa area (Booth Street and Bells Corners) and in Edmonton, in space generously provided by the Research Council of Alberta at Clover Bar. The objectives of the Centre remain the same:

(a)To conduct studies of the energy requirement of the Canadian metals and minerals industries.

(b)To assess the related transportation problems in supplying these energy needs and in developing markets for metallurgical fuels and their products.

(c)To perform both research and development work up to the pilot scale:

(i) on the production of "further-processed" metal ores (particularly reduced iron ores) ferro-alloys, and other metal products;

(ii) on the application of energy to metallurgical processes, including fossil-fuels carbonization or conversion and metal-ore reduction; and

(iii) the abatement of air pollution arising from some metallurgical processes, especially those of the ferro-alloy industry.

(d)To apply the results of these studies through:

(i) organization of co-operative formal government-industry groups, such as the Canadian Carbonization Research Association;

(ii) organization of ad hoc technical committees, such as that formed to study special problems in the hydraulic transport of coals to be used for coking;

(iii) consultation with industry, universities and government representatives; and

(iv) the preparation of reports and papers.

Pyrometallurgical Studies

The main effort of this group concerned electric-furnace production of ferro-alloys and related products. This industry is faced with a drastic need to reduce air pollution, since very fine dust is produced by the volatilization of charge constituents under the very high temperature of the electric arc. With reasonably priced electrical energy, Canada has always been in a favored position for the development of this industry. It is thus important to overcome these problems in such a way as to improve the economic position of this industry. Attention has been focused on furnaces producing silicon, and by year-end methods for markedly reducing dust formation while improving furnace performance had been devised. These techniques must now be assessed at the pilot-plant scale.

In another experimental study of air pollution in the pyrometallurgical industry conducted in co-operation with a leading non-ferrous metals producer, a pilot-scale program of volatilization of lead and other metals from flue dust was conducted. The object of this round-the-

clock investigation was to devise a method to allow recycling of these smelter waste products. Industrial application of this process awaits assessment of rival methods.

In support of studies being conducted by other industrial and research organizations, studies were undertaken on methods of pelletizing super-concentrates of an eastern Canadian iron ore as a first step in their application in one rotary kiln direct-reduction process. Promising results were obtained by blending and by choosing appropriate size ranges. Pelletizing studies were also conducted on a variety of minerals and waste materials to allow their use in subsequent processes.

An important aspect of this research is the development of instrumentation. Steady progress has been made on electric-data-acquisition equipment to improve control of the smelting furnaces and to reduce the time needed for the interpretation of the information obtained.

Coking-Coal Program and Related Studies

Severe disturbances occurred during the year in the supply of coking coal. This led to many demands on the Branch to assess the practicability of using new coals, particularly western Canadian coking coals, in the steel industry of central Canada. Accordingly in co-operation with the Department of Industry, Trade and Commerce, the Canadian Coal Producers, Transporters and Consumers Research and Development Group has agreed to discuss specific essential needs of the steel and coal industries and to make formal applications for research to the Program of the Advancement of Industrial Technology (PAIT). Two full meetings of this group were held in December 1970, and activities of this group were then co-ordinated with the current research of the Canadian Carbonization Research Association. The Department of Energy, Mines and Resources integrates the technologic aspects of its carbonization and related research with the latter organization to provide a good "coupling" with the needs of the industry and to provide an optimum use of the very restricted facilities available in Canada.

For the reasons noted above, carbonization research reached a new peak, with a total of 156 tests during the year. Efforts to relocate to the new Bells Corners site continued, and at year end only the twelve-inch movable-wall oven remained at the Booth Street site. This will be maintained in operation along with the two ovens at the new site (the new twelve-inch oven will begin operating early in the next year) until the demand for evaluation tests abates or until additional facilities are provided, possibly near the new western coal fields. In the meantime, work continues on methods of improving the technical performance of coke ovens by studies of pre-heating, use of additives, bulk-density control, etc., and improved evaluation methods with increased emphasis on petrography.

In the Western Regional Laboratory, great emphasis is placed on developing a method for the "re-constitution" of coking coal from hydraulic transmission slurries. A technically acceptable process was developed at the small pilot-plant scale. The development opens the way for the construction of pipelines to transport coking coal which hitherto had not been considered possible. A very considerable amount of coke testing in the Ottawa laboratories was needed to support this activity.

In addition to this major project, work continued on the long-range development of integrated coal-washing circuits applicable to the friable coals of western Canada; also a major project to upgrade lignite in full value to allow its more economic transport and to remove certain deleterious constituents has begun.

MINERAL PROCESSING

Research in the Mineral Processing Division has as its objective the most effective conversion and use of minerals. It comprises applied research in the fields of mineral separation, ceramics, construction materials and non-metallic minerals, and the provision of expert advice to other government departments and industry.

The Industrial Minerals Subdivision did research in mineral beneficiation, ceramics, construction materials, non-metallic minerals and waste minerals with support from the Ore Mineralogy Section. The work ranged from evaluation of mineral deposits, beneficiation and processing of industrial minerals to development of useful products such as ceramics, building materials, chemicals, fillers and composites. Some of the work was oriented largely toward materials science, where properties are determined and developed to ensure the most effective utilization of non-metallic materials.

The study of flotability of non-metallic minerals was continued by the Industrial Minerals Milling Section, and demand for additional published information on this subject was extensive. Photometric sorting was applied to the preconcentration of beryl, rare earths, and uranium. Work commenced on a project for separating sylvite from halite

by this method and on a method of comparing grindability of non-metallic ores. Mines Branch research on the flotation of celestite, a strontium mineral, helped the Kaiser Celestite Company plant in Nova Scotia to start operations. Investigations were carried out into beneficiation of Canadian ores of magnesite, beryl, feldspar, quartz, barite, spodumene, scheelite and marl.

The Construction Materials Section and the University of Ottawa started a joint project to determine the effect of below-freezing temperatures on the strength development of concrete. The durability of concrete under Canadian climatic conditions was tested in several projects. Investigations in the aggregate laboratory were made on the durability of both coarse and fine aggregate in exposed aggregate wall-panel units. Principal factors studied were effect of aggregate size, shape and grading characteristics on bonding stability with a cement matrix. This Section continued to co-operate with ASTM in developing strength-test methods, and it participated in a co-operative ASTM test series on the water requirements of different types of fly ashes in concrete mixes.

Studies were made by the Ceramic Section of the properties of new ceramic raw materials and products. High-purity alumina was prepared by a cryochemical method, and its thermal behavior was studied to provide background information on the problem of making Canadian alumina suitable for electronic substrates. A method of improving thermal-shock resistance of Canadian whiteware, stoneware, sewer pipe and flue liners was developed. The research involved the use of lithium compounds.

The preliminary apparatus was developed for the measurement of thermal diffusivity of solids based on theoretical models. Measurements performed on alumina and pyroceram specimens were in close agreement with accepted values, proving the soundness of the theoretical concept. Additional work is continuing on the development of this method.

The properties of minerals from many Canadian deposits were investigated. Clay and shale deposits were evaluated as potential sources of raw material for clay products and lightweight aggregates. Deposits of such materials as magnesite from British Columbia, talc from Ontario and British Columbia and Manitoba, limestone from Newfoundland, diatomite from New Brunswick, asbestos from Quebec, bentonite from Saskatchewan, gypsum, limestone and silica from Alberta were evaluated. Research on asbestos fibre was continued in co-operation with the Quebec Asbestos Mining Association. Work included study on the utilization of asbestos fibre for plastics, of dielectric-constant measurements as an indication of asbestos content and of the behavior of asbestos fibres in a magnetic field and the relationship between magnetic susceptibility and the magnetic content of asbestos.

Research was carried out in two general areas on metallic-ore concentration. Research on improved processes included projects on flotation and filtering.

Basic Principles of Flotation

Work continued on devising a method, based on photospectrometry, for determining and regulating the concentration of metallic ions in flotation pulp solutions. This is the principal means of developing the selectivity required to separate minerals of different metals, e.g. pyrite from chalcopyrite, sphalerite from pyrrhotite, lead carbonate from dolomite. Since copper-ion concentration is the critical determinant in the first two separations cited, work was concentrated on the complex copper-ion distributions in water.

A part of a flotation project to modify the structure of amine flotation collectors to obtain collectors specifically selective for "oxide"-type minerals has resulted in the synthesis of amine collectors that will float scheelite and lead carbonate cleanly from associated gangue minerals. A paper is being prepared for publication at the International Mineral Processing Congress, London, 1973.

Research is also continuing on a study of the electrical charges on the bubbles in the flotation process. The charge can now be measured and, if a method of controlling its sign and magnitude can be developed, it will be possible to increase the rate of flotation of very fine minerals liberated by the fine grinding required on ores such as those of New Brunswick.

Fundamentals of Filtering and Dewatering

Two plant research projects are in progress in co-operation with the Iron Ore Company and Hilton Iron Mines on the development of better filter cloths and faster filtration rates. Methods of evaluating filtration variables have been developed, including electron-microscope and streaming-potential methods.

In the second general area, the development of better methods of concentration of certain types of ores was the objective. The ores included molybdenum ores, mixed iron oxide-sulphide ores, low-grade nickel ores, tungsten ores, and a complex bismuth-tungsten-molybdenum ore.

Work was completed on a method for flotation of molybdenite ores from the Cadillac area of Quebec. These ores contain a high percentage of talc which has added greatly to operating costs in the past. A simple method was found to depress the talc and obtain a high recovery and grade of molybdenite. Unfortunately, the added problem of a depressed molybdenum market forced the two operating mines to suspend operations before the new process was ready for production trials. Its application will, therefore, have to wait for a more attractive economic situation.

Investigation of several low-grade nickel-sulphide ores has shown that the main problem in their concentration is the high percentage of nickel present as silicate minerals. The finely disseminated nickel sulphides can be liberated by fine grinding and flotation, but so far the nickel-containing silicates cannot be concentrated by physical methods.

As an assistance to new mine exploration, several investigations were carried out to define the concentration possibilities for the ores, so that their economic potential could be evaluated and feasibility of mining determined.

EARTH PHYSICS BRANCH

GRAVITY DIVISION

A major objective of the Division is to complete the regional gravity survey of the Canadian landmass, continental shelves and inland waters. The *Bouguer Gravity Anomaly Map of Canada* published in 1968 shows progress to the end of 1966. In 1971 as in past years efforts have been directed towards completing this program. Field surveys involving almost 7,000 new gravity stations have been made as follows:

1. A field party supported by two helicopters and one fixed-wing aircraft established 3,700 new gravity stations at intervals of eight miles in a large area of the District of Mackenzie and the District of Keewatin, including King William and Southampton Islands and the southern part of Boothia Peninsula.

2. Further to the north, on Banks Island, a small party supported by one helicopter established 910 new stations at eight-mile intervals throughout the island.

3. Approximately 1,500 new stations were observed at four-mile intervals on the sea ice of the Beaufort Sea. An additional 88 stations at seven-mile intervals were observed on ice immediately west of Banks Island. A major part of this survey was done in co-operation with hydrographers of the Polar Continental Shelf Project of EMR.

4. In British Columbia 167 new stations were observed on a four-mile grid adjacent to a proposed seismic experiment scheduled for 1973 in the Quesnel region.

5. Off the east coast of Canada 450 new underwater gravity stations were observed on a seven-mile grid on the Scotian Shelf. Gravity coverage in this area now extends for about 130 miles offshore and as far west as 65° 35'W.

6. A local gravity survey of the Guichon Batholith was made in co-operation with the British Columbia Department of Mines and Petroleum Resources and the University of British Columbia. About 200 stations at one-mile intervals were observed along three profiles. The results suggest a close relationship between minimum gravity values and porphyry-copper deposits.

These surveys have as usual been tied to the Primary Gravity Network of Canada. Publication of the new network has been delayed pending adoption of the International Gravity Standardization Network 1971 (IGSN71) to ensure that the new reference system for Canada will be consistent with world-wide standards. Adjustments necessary to achieve this are now in progress. The conversion from the present Potsdam standard to the new IGSN71 absolute values coupled with conversion to the new gravity reference ellipsoid (1967) involves a massive recomputation of all secondary control networks and gravity-anomaly data in the Division's file. This conversion will take about two or three years.

During the past year the Division has made a significant contribution to a special study group of the International Association of Geodesy responsible for establishing the IGSN71. Preliminary adjustments made by various participating agencies were in close agreement, and the final adjustment, involving 2,000 gravity stations around the world, was made in Ottawa with the Division's computing system. The new gravity-reference standard was adopted

in principle at the Moscow meeting of the International Union of Geodesy and Geophysics in August 1971.

In March of 1970, the Division's Datacentre installed an EAI 430 flatbed plotter. This machine has provided significant improvements in accuracy and performance over the previous plotter. A general software package has now been developed for use with IBM 360 FORTRAN IV programs, and development is continuing on an automated contouring package. In August 1971, the Department announced the acquisition of a CDC 6400 computer system, and in September the conversion of all IBM 360 programs to this system was begun. It was expected that this conversion would be completed by January 1972. During the past year, the Datacentre processed approximately 80 requests for gravity and associated data from external agencies.

Studies involving use of the gravity-survey data have progressed favorably during the year. Progress has been made in studies of vertical movements of the earth's surface related to post-glacial rebound, the eustatic rise in sea level and the elastic deformation of the earth due to the melting of late-glacial ice sheets using simplified models of the earth. The movements of the ground are large and significant and required a re-evaluation of what is meant by eustatic sea-level change. It was concluded that there is no evidence of a substantial eustatic change in sea level in the last 6,000 years and that the information of past sea levels, when sufficiently widespread, can be an important tool for studying the deep mechanical structure of the earth.

Knowledge of rock-density variations is an important part of gravity interpretation. In the Western Canadian Basin of Alberta and Saskatchewan density (gamma-gamma) logs were collected from oil companies and used in a statistical study of sedimentary rock densities. The logs were subdivided into 34,000 intervals from a total footage of 814,000 feet. All data (density, lithology, formation tops and well details) were stored on four disk files. As a result of this study a new Bouguer-anomaly map reflecting anomalous mass distributions beneath the sedimentary fill has been produced, and a clearer understanding of variations in the density of the sediments themselves has been obtained.

Bouguer and isostatic anomalies for a section across the southern Canadian Cordillera extending from the Interior Plains to the Juan de Fuca Ridge off Vancouver Island have recently been interpreted in terms of geological and crustal structure. The Bouguer anomalies are related to near-surface density variations but are distorted by the effect of elevation. This effect was removed by computing isostatic anomalies for an Airy crust (thickness 30 km) with a density contrast of 0.4 g/cm^3. Regional changes in the amplitude of these anomalies were interpreted in terms of a number of crustal blocks of different thickness, and regional changes in the density of both crust and upper mantle. Changes in crustal thickness are supported by estimates from previous seismic experiments, and the significance of the derived models in terms of the plate-tectonic history of British Columbia has been examined.

Attempts have also been made to interpret the megastructure of the Canadian Shield in terms of plate tectonics. A hypothesis has been developed which suggests that the Superior and Churchill Provinces were once separated by seas but are now welded together along a geosuture which extends around the periphery of the Superior Province from Manitoba through Hudson Bay to the Labrador Trough.

The Division has recently commenced a new program of detailed gravity investigations in areas of known economic importance or potential. The first area studied was the Sudbury Basin. A rigorous study of old and new gravity data has resulted in a series of new gravity maps (Bouguer anomaly, first vertical derivative, second vertical derivative, etc.) and a new three-dimensional model of the Sudbury structure. In 1972, attention will be focussed on a section across the Labrador Trough which contains some of the best-preserved geosynclinal rocks in the Shield. Gravity is considered to be a potentially useful tool in elucidating crustal evolutionary processes in the Trough. Regional gravity measurements have already revealed a highly anomalous field related to the Trough and its margins.

A major program of earth-tide research was continued with emphasis on the problem of correcting for the attraction and loading effects of the ocean tide. This correction is necessary before the earth tide can be determined, and knowledge of the ocean-tide effect is itself useful because of its dependence on the mechanical structure of the crust and upper mantle. Methods for calculating the ocean-tide effect on inland earth-tide gravity and tilt measurements throughout the world have now been developed. The calculated results are consistent with North American and Western European observations but inconsistent with Eastern European and Asian observations. This result may indicate a systematic difference in the elastic parameters for Asia or an error in the assumed ocean-tide distribution.

A finite-element method for determining the Green's function of an earth with an arbitrary crust and upper mantle structure has been developed in co-operation with Dalhousie University. This method has been successfully applied at a coastal site on the Bay of Fundy where the crust appears to be 35 km thick and underlain by normal mantle differing from the Appalachian-type crustal structure under the Gulf of St. Lawrence.

Efforts in instrument research have been concentrated on developing an earth-tide-meter calibrator. A prototype has been developed in which a known sinusoidal vertical acceleration with a period of 100 seconds is applied. Calibration accuracy of between one and two per cent was achieved, and modifications now in progress are expected to improve the accuracy to 0.1 per cent at 1,000 seconds. Two North American gravimeters have been converted to recording earth-tide meters of the TRG-1 type.

A water-tube tiltmeter is also being tested. Resolution of 0.1 per cent tidal amplitude without apparent "stiction" or hysteresis effects has been demonstrated. This instrument should have wide application in the future.

Preparations have also been in progress during the year to develop equipment for systematic tilt measurements on the Arctic Ocean. This project is part of an international venture called Arctic Ice Dynamics Joint Experiment (AIDJEX) which will take place in 1974, although pilot studies began in 1969. Test measurements of ocean tilt have already been made in the Arctic Ocean and Gulf of St. Lawrence. The next test will be made in the Beaufort Sea in 1972.

In the field of physical geodesy, computations have been made of the deflection from gravity data at a few related astro-geodetic stations. Preliminary analysis has shown that for the required accuracy, additional gravity surveys around the computation point are required. These surveys are now in the planning stage. Methods are being developed for computation of the integral of Stoke's function over a block of given degree size, and the Division is studying its use in the computation of the standard error of geoidal height from a knowledge of the standard errors of the mean gravity values over individual blocks. A method is also being developed to compute fully normalized associated Legendre functions for use in spherical harmonic analysis of world-tide gravity data.

The Rock Physics Section continued its investigation of fossil meteorite craters and the related study of hypervelocity impacts. Unlike previous years, relatively little time has been spent on discovery, mapping, petrography and other descriptive aspects necessary to confirm the suspected impact origin of circular topographic features. The one notable exception is that Lake Wanapitei, at the northeastern end of the Sudbury Basin, has been definitely established as a meteorite crater. A circular negative Bouguer anomaly of 14 mgals in the lake, plus the discovery, in breccia boulders on the lakeshore, of the complete range of shock-deformation features typical of meteorite impact serves to confirm this origin. Coesite, a high-pressure silica polymorph occurring naturally only in meteorite craters, and possibly some meteorites, has been identified by X-ray in a largely glassy fragment of Lake Wanapitei breccia. Although coesite has been reported from a few other terrestrial craters, this is the first incontrovertible find in a Canadian crater. Skeleton Lake, Ontario, has been considered as a probable meteorite crater for a few years, and the existence of a circular-negative Bouguer anomaly in the lake has now been confirmed. Several other possible meteorite-crater sites have been noted and some have been rejected after a preliminary examination of appropriate maps and aerial photography, but most await further study. Eight samples suspected to be meteorites were submitted by both geologists and the public for identification. One of these was confirmed as a meteorite and added to the National Collection.

Recent petrographic studies have investigated the composition of impact melts and shock effect in potassium feldspars. In order to be able to equate natural shock-metamorphism features with conditions of formation, shock experiments were carried out on potash feldspars at the California Institute of Technology, where pressures up to 413 kb were attained.

In a continuing program in collaboration with the Geological Survey of Canada, lunar samples from Apollo 12 and 14 missions were investigated, with particular emphasis on shock effects in breccias and "fines." The Rock Physics Section was also called upon to provide scientific assistance during the geological training exercise for Apollo 16 astronauts held in the Sudbury Basin, Ontario.

SEISMOLOGY DIVISION

The standard network of seismic observatories equipped with short- and long-period seismographs continued operating as in the past, except that the Halifax station was reduced from a first-order to a second-order station with only one short-period vertical seismograph. In addition, to give better coverage of local events in eastern Canada, a second-order station similar to Halifax was installed at Fredericton, N. B.

An additional specialized narrow-band, high-gain, long- and short-period seismograph was installed at Suffield, Alberta, to supplement records from a similar seismograph operating at Alert, N.W.T. Similar but more sophisticated installations were planned for Penticton and Mould Bay later in 1971. Experiments on and modifications to these instruments are carried out in Ottawa before they are shipped to their ultimate destinations.

Improved use of available computer services resulted in a more rapid and complete check on the approximately 30,000 P phases reported annually by the network stations. This also permitted faster service to world data centres at Rockville, Maryland (NOA), and Edinburgh, Scotland (ISC).

Quality control and instrument calibration were maintained at all stations of the Canadian network by a schedule of routine field inspection trips by staff members.

Studies of Canadian seismicity continued. A project was undertaken jointly with Laval University to study the seismicity of the St. Lawrence Valley near Malbaie, Quebec, during the summer of 1970. The strong-motion seismic network deployed along the west coast of Canada obtained the first really significant strong-motion spectra from Canadian earthquakes. The results have been analysed and will be made available to the earthquake-engineering community.

A number of papers were published concerning primarily the core and inner-core structure of the earth. As a result of this work, travel times were calculated for previously unidentifiable seismic phases. Crustal-response functions for sources and station sites were determined theoretically, making possible the calculation of theoretical seismograms for nuclear explosions and teleseismic events. Surface waves, as recorded by the Canadian standard-station long-period network, were used to conduct a reconnaissance study of lithospheric thickness in Canada.

The results from a crustal-refraction survey in the Yellowknife region of the Northwest Territories were published. These show that the gross structure of the region is as simple as any yet discovered in Canada. One feature of interest is that the M discontinuity beneath the East Arm of Great Slave Lake, believed by geologists to be a major graben, is strongly depressed. Work continues on the massive suite of data recorded last year along a 100-km line near Yellowknife. Tentative results indicate the presence of a well-defined low-velocity channel in the upper crust.

The results from a crustal-refraction profile northwest of the Queen Elizabeth Islands out over the Arctic Ocean indicate that the crust is thinning from normal continental thickness at the coast to that of a normal oceanic crust under the Canadian Basin.

A major theoretical advance was achieved in the use of synthetic seismograms for the interpretation of crustal-refraction data obtained earlier in the province of Quebec. This demonstrates without doubt the existence of a low-velocity crustal layer along the Grenville Front. The layer provides an explanation for one of the largest gravity anomalies in eastern Canada.

During the year a synthesis of geophysical observations in the Canadian Cordillera was completed and sent to press. This work will provide guidance for geophysical activities in western Canada in the immediate future.

The geothermal group continued to make field measurements, mainly in the Shield, the Cordillera and the Arctic Islands. A gamma-ray spectrometer was put into operation, measuring the heat production of rock samples, in order to relate heat flow to heat production in the crust. Several papers have been published, including measurement and analysis of heat flow in the Kapuskasing area and estimates of the disturbance of heat flow due to climatic changes.

A great deal of effort has been diverted into permafrost studies. The techniques of measurement of temperature and thermal properties of rock that have been developed for heat flow work are of importance in permafrost research. Several dry oil-exploration wells in the Arctic have been preserved for accurate temperature surveying, and plans were made to make measurements of the thermal properties of frozen sediments in the Mackenzie Valley during the summer of 1971.

A tripartite long-period seismic array was commissioned in conjunction with the short-period Yellowknife Array at Yellowknife, N.W.T. Signals from the remote stations are transmitted to the base station by radio-telemetry links and, in the same way, all calibration and control functions are regulated from the base station. Planning was completed for changeover of the short-period array to two-way radio telemetry during 1970-71.

A detailed evaluation of present world-wide seismic capabilities entitled *Seismological Detection and Identification of Underground Nuclear Explosions,* was prepared for distribution by the Canadian Government at the 26th General Assembly of the United Nations.

An experimental study of laser-strain-gauge seismology was completed in the Ottawa seismic vaults. As a result, it was decided that mechanical rather than laser technology was more appropriate for this work. Instrumentation for a dual-band seismograph with optional recording was designed and built.

The geodynamics group continued to observe the earth's rotation and the motion of the pole with photographic zenith tubes (PZT) near Ottawa and Calgary. The latter instrument, since mid-1968, co-operates with the Royal Greenwich Observatory (Herstmonceux), on the same parallel, in a common program of observations to detect relative motions in longitude and latitude due to continental drift. Both instruments contribute with high weight to the international services monitoring rotation and polar motion (Bureau International de l'Heure, B.I.H., International Polar Motion Service, I.P.M.S.). Ottawa observations since 1956 have been reduced to a homogeneous basis and analysed for periodic and secular terms; an improved catalogue has been prepared. Detailed results of observations at the Ottawa and Calgary sites up to December 1970 are in press. Both are first-class instruments and are producing observations of polar motion to an accuracy which is unsurpassed in the world.

GEOMAGNETISM DIVISION

The information on the direction and intensity of the earth's magnetic field shown on the magnetic charts of Canada, aeronautical and marine navigation charts, and topographic maps comes from high-level airborne surveys carried out by the Division of Geomagnetism. The 1970 survey covered Canada's Arctic islands and about one-third of the Arctic Ocean—the part between the north geographic pole and the Canadian landmass, Greenland, and Spitzbergen. Magnetic measurements were recorded continuously along 22 parallel flight-lines spaced 40 miles apart, for a total of 50,000 miles of flying in a chartered DC-6B aircraft.

In addition to providing vital information for navigation on over-the-pole airline routes, the survey mapped the large-scale patterns of magnetic anomalies associated with ocean ridges. These anomalies trace the history of formation of the Arctic basin, and their study is expected to lead to a better understanding of the processes which have formed deposits of oil and gas in Canada's Arctic.

Magnetic charts must be revised every five years because the geomagnetic field is constantly changing. To bring up-to-date the data from earlier surveys, measurements are made on the ground every few years at each of 100 carefully marked repeat stations, uniformly distributed over the country. During 1970, 25 such stations were occupied, mainly in the western Arctic.

Charts at a scale of 1:10,000,000 were published showing the direction and rate of change of the magnetic field over Canada and the neighboring oceans as of 1970.

The natural variations of the geomagnetic field were recorded continuously at magnetic observatories in the following locations: Alert, Resolute, Baker Lake, and Mould Bay, all in the Northwest Territories; St. John's, Newfoundland; Poste de la Baleine, Quebec; Ottawa, Ontario; Churchill, Manitoba; Meanook, Alberta; and Victoria, British Columbia. In addition to the permanent observatories, unattended magnetic recording stations were operated in Manitoba at Lynn Lake, Thompson, The Pas, and Winnipeg, in a co-operative research project with the United States National Aeronautical and Space Administration involving the synchronous satellite ATS-5. Research included the study of several intense magnetic storms centred in the western Arctic and a detailed analysis of rapid variations (micropulsations) recorded simultaneously at four observatories covering a wide range of latitude.

Further field investigations in the Arctic islands revealed that the rocks of anomalously high electrical conductivity which underlie Prince Patrick and Melville Islands extend beneath Banks Island and the northern part of Victoria Island. A reasonable explanation of this remarkable feature remains to be found. Other field studies of deep crustal electrical conductivity were made in central British Columbia, Baffin Island, and southeastern Quebec.

The paleomagnetic group collected and studied the magnetization of rocks from the central Northwest Territories, and from Vancouver Island. Preliminary results indicate that 200 million years ago Vancouver Island was not part of the North American continent, but was thousands of miles away in the central Pacific.

Good progress was made in geomagnetic instrumentation. By the end of 1970, four of the ten magnetic observatories were equipped with instruments, developed in the Division's laboratories, which produce a record on digital magnetic tape, ready for the digital computer. This advance not only makes possible unmanned automatic observatories, but also makes practical sophisticated analyses by computer which were previously out of the question.

POLAR CONTINENTAL SHELF PROJECT

The Polar Continental Shelf Project is a continuing investigation of the continental shelf fringing the Arctic coast of Canada, together with adjacent parts of the Arctic Ocean basin, the islands of the Canadian Archipelago and the waters between them, and other areas that may be of special interest. The project serves in part to facilitate Arctic researches and surveys of other units of the Department of Energy, Mines and Resources; in part it carries out, with its own personnel, work that is unique within the Department; it also serves as the vehicle through which the investigations of other agencies are carried out in the Arctic Archipelago and the Arctic Ocean; and it provides facilities and support for approved university researches in the area.

The project's field survey will eventually cover all the Canadian sector of the Arctic continental shelf of North America, those parts of the Arctic Ocean that are of interest to Canada and which can be reached with available logistics, and those parts of the archipelago and the mainland not studied by other agencies of the Department.

Field activities in 1971 were carried out from mid-February to early October. A small program of sea-ice investigations was undertaken in January, February and December. The main bases of operation were Tuktoyaktuk, Resolute Bay and Alert.

In addition to EMR, 42 other agencies were involved in or received assistance from the operations of the PCSP. Among them were 24 universities. Twenty agencies were associated with the Arctic Ice Dynamics Joint Experiment (AIDJEX) and the International Biological Project Tundra Ecosystem Study.

The 1971 program was, in the main, a continuation of that of 1970. The main emphasis was placed on the Beaufort Sea.

The following is a summary of the work done in 1971, by major scientific fields:

Climatology

Study was continued by a scientist from McGill University under contract to PCSP of the present behavior of a small high Arctic icecap—the Meighen Island icecap—and its influence on and reaction to the local climate. Emphasis was laid on the energy exchange between atmosphere and the earth's surface of known uniform physical properties.

Hydrography

A survey (ocean soundings) of the Beaufort Sea was made for charting at a scale of 1:500,000 by the PSCP Hydrographic Section with assistance from the Canadian Hydrographic Service (DOE). Soundings were also taken in Robeson Channel at a scale of 1:1,000,000, near Hans Island in Kennedy Channel at a scale of 1:1,000,000; and in the vicinity of Wrangel Bay at a scale of 1:10,000.

Sea-Ice Studies

For the tenth successive year, a systematic aerial survey was carried out of the distribution, nature and movement of sea ice in the main channels of the Arctic Archipelago.

Position Determination

Already existing control positions on the Greenland and Canadian coast were used in 1971 for a hydrographic survey of Robeson Channel. After an evaluation was made of the Omega navigation system and the Decca Lambda system, it was concluded that the Decca Lambda system was the most suitable navigational system in high latitudes.

Geology, Marine

Continuous seismic-reflection profiling and side-scan sonar work in the Mackenzie Bay area and Beaufort Sea area north of Tuktoyaktuk indicate a large ice-scour canyon, now almost completely filled up, to have existed in Mackenzie Bay. The existing Mackenzie canyon on the bathymetric charts is that part of the ice-scour canyon that has received the least amount of sediments since glacier retreat. These studies were undertaken by scientists of the Geological Survey of Canada, supported by the PCSP.

Geology, Terrestrial

The study of Cretaceous rocks in the Yukon coastal plain by the Geological Survey supported by PCSP was continued in order to outline the stratigraphic succession, lateral variations and the ancient environments of deposition to determine possible coal reserves and areas favorable for petroleum accumulation. An experimental study of

the use of "shallow seismic" techniques to investigate the occurrence, depth and thickness of permafrost in different local geological settings was begun. Preliminary maps of terrain and surficial deposits of the Coastal Plain, Alaskan boundary to Cape Bathurst, at a scale of 1:125,000 were completed and placed on open file (Geological Survey).

Investigations of Pleistocene stratigraphy by the Geological Survey throughout the length of the Eskimo Lakes were continued. Detailed mapping of Herschel Island was completed. Detailed mapping at a scale of 1:25,000 to locate sources of aggregate and delineate geologic problem areas in the vicinity of Tuktoyaktuk was begun. Studies on the occurrence of ground ice and permafrost thickness using resistivity and seismic methods continued. Investigations by the Geological Survey into the origin and growth of ground ice and temperatures in permafrost were also conducted in various areas of the Mackenzie Delta and Valley.

Geomagnetism

Studies of the anomaly in geomagnetic induction on Ellesmere Island by the Earth Physics Branch, supported by the PCSP were extended to the north, with four temporary stations on the ice of the Lincoln Sea northeast of Alert. Analysis of the data indicates that the principal features of the anomaly extend into the continental shelf.

Gravity

Regional mapping of gravity by scientists of the Earth Physics Branch, supported by the PCSP continued, approximately 1,600 gravity measurements being taken on the sea ice over the Beaufort Sea at a station interval of about four miles and approximately 900 measurements being taken over Banks Island at a station interval of about eight miles. A gravity map is being compiled for the Beaufort Sea and Banks Island at a scale of 1:1,000,000. An experimental study to investigate the use of gravity in locating and investigating the thickness of ground ice was conducted over Tuktoyaktuk Peninsula and Richards Island.

Geothermal Studies

Temperature measurements by the Earth Physics Branch have been made at yearly intervals in eleven deep boreholes to determine the thermal recovery from drilling and the equilibrium geothermal gradient. The equilibrium temperatures yield a permafrost thickness at the location. A program was begun to study the thermal regime of the subsurface and to measure the thermal parameters of the overburden material in permafrost terrains, first results being obtained in the vicinity of Fort Good Hope, N.W.T. These studies were supported by PCSP.

Glaciology

Studies of the mass balance and physical behavior of Arctic icecaps by PCSP glaciological section continue. Following studies of Meighen icecap, the crystallography and internal structure of the Devon Island icecap is being studied to determine its history and the climate of the region during the recent geological past. A core containing a complete sample of precipitation, particulate fallout and other impurities over the past 2,000 years has been obtained.

Frozen-Sea Research

The objective is to obtain a complete picture of seasonal variations in water structure associated with growth and decay of sea ice. It is hoped that precise measurement of salinity, temperature, currents and oceanographic conditions will lead to an explanation for vertical mixing associated with salt rejection by sea ice during growth. An under-ice traversing probe to record horizontal variations in temperature and salinity beneath growing sea ice is being developed. Work has begun on measuring the change of freezing point of sea water with pressure. Studies of runoff in Arctic regions have been completed as an aid to understanding seasonal changes in the surface waters. These studies are conducted by the Water Sector, Environment Canada, and extensively supported by PCSP.

AIDJEX

The Arctic Ice Dynamics Joint Experiment is a common purpose and a co-operative effort to understand quantitatively the interaction between the fields of motion of the atmosphere, the pack ice, and the liquid ocean. This understanding is basic to forecasting ice conditions and to assessing variations in surface/atmosphere circulation. Preparation for AIDJEX, whose main program is scheduled for 1973-74, are continuing, and a major pilot study was conducted in the Beaufort Sea in 1971. The purposes were to test instruments and techniques for measuring absolute and differential water-velocity profiles under freely drifting pack ice, determination of ice strain and deformation, observation and mapping of the undersurface of drifting ice, and determination of the differential translation of separated points on the drifting ice under

different wind conditions. As an associated part of this pilot experiment, methods were tested for determining the tilt of the ocean surface.

Other Activities

PCSP provided support for several other projects such as: a micrometeorological study of wind and temperature to establish air drag coefficients of the ice cover by Atlantic Oceanographic Laboratory; an investigation of beach characteristics in the Radstock Bay area by McMaster University; live capturing, tagging and branding of ringed seals by Fisheries Research Board; collection of about 700 species of insects to assist in the knowledge of distribution of insects in the north by Canada Dept. of Agriculture; population and movement of polar bears by Canadian Wildlife Service; chlorophyll and dissolved organic carbon content at the base of sea ice by the Dept. of Sea and Shore Fisheries, state of Maine, USA.

ATLANTIC GEOSCIENCE CENTRE

(During the period under review, i.e., April 1970-March 1971, the units now making up the Atlantic Geoscience Centre were part of the Water Sector. This Sector was later transferred to the Department of the Environment, with the exception of the above-noted units.)

HUDSON 70

Participation in the HUDSON 70 circumnavigation of the Americas, under way since November 1969, very much dominated the activities of both the Marine Geology and Geophysics Sections for this year. The HUDSON 70 cruise ended in October 1970, and with it the fieldwork and data acquisition of the program. Reduction and interpretation of results, however, will occupy both Sections for quite some time to come.

For the earth sciences the following activities and discoveries highlight the expedition:

(a) The completion of the longest gravity line along a meridian (150°W) from the Antarctic ice to the Alaskan shelf. This line will help provide a ground reference (accurate shape of the geoid) for U.S. satellite measurements of the height of the sea surface which are to begin in 1973.

(b) A geophysical survey off Canada's west coast provided information on the interaction and movement of large segments of the earth's crust and helped define the pattern of continental drift (sea-floor spreading). CSS *HUDSON* in combination with CNAV *ENDEAVOUR* carried out a seismic experiment which showed that the propagation of sound under the earth's crust varies directionally, contiguous with the direction of sea-floor spreading.

(c) An extensive bottom-sampling program established the sediment distribution in the Beaufort Sea. Also in the Beaufort Sea submarine ice-cored hills or pingoes and deep scours caused by movement of ground ice were discovered. Both features indicate potential hazards. The former, generated by the expansive force of freezing water originally locked in sandy aquifers, form shoals which may endanger navigation. Ice scouring could destroy man-made structures put down on the sea floor, such as pipe lines and well heads.

(d) Seismic refraction shooting established that Baffin Bay is underlain by oceanic crust, which provides an all-important clue to the unravelling of the geological history of Northeastern America and Greenland.

Sinking of ARROW

The grounding and sinking of the Liberian tanker *ARROW* in February 1970 released 2.5 million gallons of Bunker C oil, polluting Chedabucto Bay and its shore. This year has seen extensive research as a direct result of the *ARROW* disaster. Within the Geology Section the long-term observation on Crichton Island of natural cleaning processes is still going on. So far it has been established that some sandy portions of the seashore were cleaned in a matter of months. Conditions on bouldery and rocky shores, although greatly improved after a few months, apparently take some more time to permit erosion to remove the last stain.

General Research

Results of other research activities during this year may be summarized as follows:

Laboratory tests indicate that humic compounds associated with marine sediments exert a strong solubilizing

effect on trace metals. One gram of humic acid can liberate up to 0.7 gram of metal from insoluble salts.

Mercury in a river and estuary system is concentrated by suspended particles to levels 20 times that found in bottom sediments. In the case of the La Have estuary the metal may be exported to the ocean in quantities of one to two kilos.

The establishment of the pattern of sediment transport in the Bay of Fundy and Minas Basin was completed during this period, using a submersible for direct observations. These studies elucidate some of the problems related to the planning, construction and operation of a tidal power plant.

Seismic reflection studies suggest the presence of end-moraines parallel to the west coast of Newfoundland.

Compilation of geological and geophysical data obtained from the continental margin off Labrador and eastern Newfoundland is under way in order to establish the development of this margin.

The Regional Geology group has been compiling and analyzing geological and geophysical data that relate to various aspects of bedrock and surficial sediments underlying the Scotian Shelf and adjacent areas. The first of a number of 1:1,000,000 charts showing the distribution of unconsolidated sediments was published. Contour maps of the bedrock structures are in varying states of preparation.

Micropaleontologists monitored the environment by studying the seasonal variations and the geographical distribution of microorganisms (benthonic foraminifera) living near sewage and industrial outfalls.

With the scanning electron microscope, microstructures of foraminiferal tests were discovered that have not been reported before. These structures will assist in a better understanding of foraminiferal taxonomy and ecology and lead indirectly to a better foraminiferal biostratigraphy and paleoecology.

As special projects the construction of the new electric rock-coring drill deserves mentioning, since it makes possible the recovery of longer core samples of importance for petrological and textural analyses of bedrock, for the production of subsurface geology maps.

This year saw the completion of the analysis of the gravity data from the mid-Atlantic Ridge survey. This forms part of the continuing 45°N-to-46°N geotraverse project. Small-scale trends in structure, which had so far remained undetected, show up as a result of the trend analysis of gravity, magnetics and bathymetry.

Of prime importance for both the Geology and Geophysics Sections is the work that has been going on in the upgrading and improvement of the seismic-exploration techniques. This work is continuing and shows direct results by providing better seismic records in terms of penetration and resolution. The great improvement this year was the application of a slacking or yo-yo winch, enabling the hydrophone array to be stationary in the water while recording reflected signals. This operation immediately cut out an important part of the noise spectrum. Programs for data processing to further improve the signal/noise ratio (deverberation, stacking, cross correlation) are in advanced stages of preparation.

A new sonobuoy has been constructed, facilitating the shooting of complete crustal sections in the deep ocean. These crustal profiles are essential for the understanding of the deep processes that have shaped our earth and at the same time provide information for the correct interpretation of seismic reflection profiles. For work on the continental shelf where thick crust is encountered incorporation of recording systems in the buoys is being planned.

Work has started to improve the accessibility of geophysical data already collected by storing information in geographic order. This will allow a much more efficient usage of information, greatly improving its value. Plans are under way to improve the presentation of the data in a number of ways—numerical, profile, diagram, contoured chart, etc.—as required by the individual user.

Administration

The administrative units of the Department of Energy, Mines and Resources consist mainly of the executive offices of the Minister and senior officers and various supporting units serving the entire Department—Finance and Administration, Personnel and Organization, Public Relations and Information Services, Computer Science Centre.

During the year under review, an executive committee was formed at the highest level, with the task of co-ordinating departmental policy and planning, in the light of existing government policies and the activities of other federal departments. The committee consists of the deputy minister, who is chairman, the assistant deputy ministers, the senior advisers for finance and administration and personnel, and the director of the departmental planning branch.

A departmental management committee was also established, to deal with matters relating to overall departmental management and policies and to co-ordinate major projects. The committee is chaired by the deputy minister and consists of all members of the executive committee and senior departmental managers.

The Computer Science Centre, which serves the entire Department, was steadily increasing its computing capacity.

FINANCE AND ADMINISTRATION

The Finance and Administration Branch provides the Department with services in accounting, finance, program forecasts and estimates co-ordination, parliamentary matters, preparation and co-ordination of submissions to Treasury Board and the Governor in Council, co-ordination of memoranda to Cabinet, management of material, property planning and management, telecommunications, mail, central records, technical field support (material and equipment), and related areas. During the year, steps were taken to establish a departmental management-consulting service. This unit, when operative, will study management problems and assist in their solution throughout the department.

Planning was completed for the construction of additions to the laboratory wing and library of the Institute of Sedimentary and Petroleum Geology at Calgary. Plans were also furthered for the construction, by the Department of Public Works, of a high-rise general-purpose office building in EMR's complex on Booth Street in Ottawa.

Effective October 1, 1970, departmental purchasing was consolidated, with a small number of exceptions, in the Department of Supply and Services.

PERSONNEL AND ORGANIZATION

The Department, in its personnel administration, continued to deal with problems common to the whole Public Service—in fields such as job classification, staff relations and manpower appraisal and planning. In addition to these normal activities, because of a major interdepartmental reorganization, it planned and carried out, during the last quarter of 1970-71, the orderly transfer of the whole Water Sector and a part of the Department's administrative support personnel. This resulted in the transfer of 2,214 man-years' authority (Water Sector) and 81 headquarters administrative positions in support of this group.

At its peak employment date during the year, the Department had 6,200 employees on strength, with the technical,

scientific and professional categories accounting for approximately 60 per cent. This number included over 1,200 post-secondary school students who were employed on field surveys and in laboratories and offices during the summer. During the latter half of the year, planning was carried out for an exceptional student employment effort for the summer of 1971. These proposals, which were eventually approved by the government, resulted in the employment of some 1,650 more students in the summer of 1971 than were provided for in the original budget.

A total of 1,690 continuing appointments were made during the year, including new appointments, promotions and reclassifications. During probation, 25 employees were rejected and released.

The new departmental safety and accident prevention program was established and put into effect during the year. Despite the fact that the maximum departmental population reached its highest point, the trend towards a progressive increase in the number of accidents was reversed.

In aid of effective manpower planning, appraisal systems were designed and developed for occupational groups in the Scientific and Professional, Administrative and Foreign Service and Technical categories. A number of analytical studies concerning manpower forecasting and utilization were carried out. And a manpower planning process, for general application throughout the Department, was developed.

In training and development, some 537 employees participated in 28 in-house courses—mainly in management-improvement techniques and supervision. Language training, mainly French, was given to 326 employees. A total of 64 employees were assisted to varying degrees in furthering their formal education at universities and institutes.

An organizational study of the Water Sector, aimed at enabling it to assume its assigned role in the implementation of the Canada Water Act, was undertaken. Organization studies and reviews were also carried out in the Mineral Resources Branch and in connection with the proposed Remote Sensing Centre. A study of the senior structure of the Department was also commenced following the decision to transfer the Water Sector to the Department of the Environment.

The Department's Incentive Award Program continued to be a vigorous one. The 1970 Outstanding Achievement Award of the Public Service was presented to an officer of Energy, Mines and Resources—Dr. J.M. Harrison, Assistant Deputy Minister, Mines and Geosciences. The Department recommended six officers for Merit Awards during the year and continued to be one of the leaders within the Public Service in the use of this management tool. In the Suggestion Award Program, too, an upward trend continued in savings resulting from suggestions implemented.

The Department's health program, especially in the areas of addiction and mental illness, continued to be effective. During the year, several other departments sought advice and guidance on the implementation of similar programs.

The conversion of positions to the new classification system was largely completed and the backlog of classification grievances was overcome. Classification actions continued high, however—2,755 jobs were reviewed during the year. Training in job-description writing and classification was provided to line management by means of seminars and workshops.

The administration of 35 collective agreements was an important aspect of personnel management during the year's operations. Management was not, for the most part, familiar with a collective bargaining regime, and a considerable amount of time and effort was devoted to development of guidelines and advice to and training of managers. Departmental officers effectively participated, on behalf of Treasury Board, in bargaining activities in respect of eight different occupational groups.

The effects of collective agreements on field survey operations required special study, adaptation and negotiation to obviate difficulties caused by the variegated make-up of parties.

PUBLIC RELATIONS AND INFORMATION SERVICES

The Public Relations and Information Services Branch informs the public of the work done by the various units of the Department and the reasons for departmental policies.

HUDSON 70 was the Department's scientific highlight of the year as the Canadian Scientific Ship *HUDSON* carried out her 11-month 41,000-mile oceanographic expedition around South and North America. Ministerial news conferences were held in Valparaiso, Chile, in April; in Vancouver in June before the ship proceeded to the Arctic to carry out an extensive program of work in the Beaufort

Sea, returning to Halifax through the Northwest Passage, and at Halifax in October at the end of the expedition. Throughout the expedition, news coverage was excellent. HUDSON 70 medals commemorating the epic voyage were given out to all who participated in its planning and execution as well as to the Governor General, members of the Senate and House of Commons and newsmen who travelled to Chile.

Over 800,000 copies of the pamphlet, *Water Pollution and You,* were requested and distributed to students and teachers of high schools and colleges. A series of four water pamphlets was produced in response to requests for information on water pollution and water management.

News conferences were arranged in connection with amendments to the Canada Water Act, the Qu'appelle River Basin Agreement, the Saint John River Basin Agreement, the opening of the Research and Development Building of the Canada Centre for Inland Waters, the signing ceremony for the financing of the Hydro Quebec Research Institute, and Canadian Government approval of applications for the export of natural gas from Canada.

Information arrangements were made for the Canadian Conference on Coal at Vancouver, the Eastern Offshore Symposium in Ottawa, and the Conference on Achieving Environmental Awareness of the Canadian Commission for UNESCO in Hamilton.

The Department sponsored two classroom filmstrips, *Aluminum* and *Iron and Steel* in English and French. Twelve one-minute TV newsclips on water pollution and water management, geophysics, geology and mapping were produced in both languages and distributed and used nationally.

Two films were completed in co-operation with other government departments: a short film on the voyage into the Arctic of the *MANHATTAN* and a half-hour documentary of the *ARROW* oil spill on the east coast. The film *Every Square Inch* and an internal training film on hydrographic surveying were produced.

During the year, the Public Relations and Information Branch handled some 23,000 pieces of mail, including requests for publications and enquiries of a general nature.

The Publishing Division maintained a heavy schedule that included the issue of five oversize books as well as the normal quota of publications of a scientific or technical nature originating from all branches. In addition, the Division undertook to continue editorial responsibility for a number of publications of the former Policy and Planning Branch, now with the Department of the Environment.

A much higher proportion of contemporary design in covers and layout was evident during the year, and a new design concept was proposed for the Geological Survey of Canada series.

The French Publishing Section was designated as a Francophone unit.

The Director of PRIS was seconded to Treasury Board for a six-month period to direct the preparation of a Career Development Manpower Plan for the Information Service Officers of the federal government. Four Information Service Officers served on three of the project's six study teams.